DECEMBER 1961

Journal

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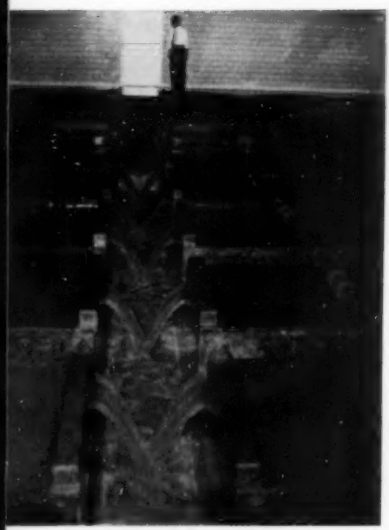
AMERICAN WATER WORKS ASSOCIATION



Supine Christmas tree formed by filters at Detroit's Springwells Plant washes you Season's Greetings

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1962 AWWA CONFERENCE
Philadelphia, June 17–22

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Journal

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December 1961

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Coming Meetings

AWWA SECTIONS

Winter-Spring 1962

Jan. 23—New York Section, Luncheon Meeting at Statler-Hilton Hotel, New York, N. Y. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Feb. 7–9—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Chester H. Canham, State Board of Health, 1330 W. Michigan St., Indianapolis 7.

Feb. 15—New Jersey Section. Winter Luncheon Meeting at Hotel Essex House, Newark. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Mar. 15—New England Section, at Statler Hotel, Boston, Mass. Secretary, Ralph M. Soule, San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

Mar. 28–30—Illinois Section, at Sheraton-Towers Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engineer, Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Apr. 5–7—Montana Section at Bozeman. Secretary, A. W. Clarkson, Div. of Environmental Sanitation, State Board of Health, Helena.

Apr. 11–12—New York Section, at Manger DeWitt Clinton Hotel, Albany. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Apr. 12–13—West Virginia Section, at Hotel Morgan, Morgantown. Secretary, Thomas J. Blair III, Kelley, Gidley, Staub, Inc., 5418 Mac Corkle Ave., S.W., Charleston.

Apr. 15–18—Southeastern Section, at Wanderer Resort Motel, Jekyll Island, Ga. Secretary, N. M. deJarnette, Robert & Co. Assocs., 96 Poplar St., N.W., Atlanta, Ga.

Apr. 24–26—Nebraska Section. Secretary, Charles W. Durham, Cons. Engr., Henningson, Durham & Richardson, 2963 Harney, Omaha.

Apr. 27—California Section, at Ahwahnee Hotel, Yosemite Valley. Secretary, Frank F. Watters, Hydr. Engr., Public Utils. Com., State Bldg., Civic Center, San Francisco.

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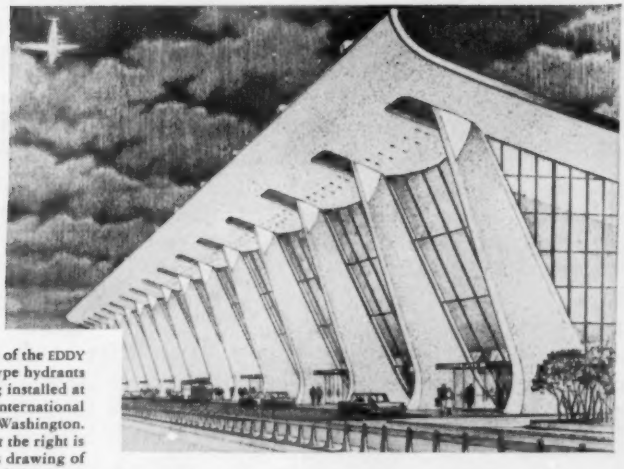

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Coming Meetings

(Continued from page 6)

Apr. 29–May 3—Canadian Section, at Royal York, Toronto, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

May 2–4—Kansas Section, at Lassen Hotel, Wichita. Secretary, F. Harry McBride, Sales Engr., B-I-F Industries, 2108 W. 75th St., Prairie Village.

May 3–5—Arizona Section, at Pioneer Hotel, Tucson. Secretary, A. D. Cox Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

May 30–June 2—Pacific Northwest Section, at Olympic Hotel, Seattle, Wash. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane, Wash.

Fall 1962

Sep. 12–13—New York Section, at Lake Placid Club, Lake Placid. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Sep. 12–14—Michigan Section, at Jack Tar-Lansing, Lansing. Secretary, T. L. Vander Velde, Chief, Water Supply Sec., State Dept. of Health, DeWitt Rd., Lansing.

Sep. 12–14—Virginia Section, at Golden Triangle Hotel, Norfolk. Secretary, Edward H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond 20.

Sep. 19–21—North Central Section, at Hotel Lowry, St. Paul, Minn. Secretary, Carl A. Flack, Registrar, Water Dept., 216 City Hall, St. Paul, Minn.

Sep. 26–28—Wisconsin Section, at Eau Clair Hotel, Eau Claire. Secretary, Harry Breimeister, Bureau of Engrs., Rm. 607 Municipal Bldg., 841 N. Broadway, Milwaukee.

Sep. 26–29—New Jersey Section, at Hotel Dennis, Atlantic City. Secretary, Albert F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Sep. 30–Oct. 2—Missouri Section, at Governor Hotel, Jefferson City. Secretary, Warren A. Kramer, 4th Floor, State Office Bldg., Jefferson City.

Oct. 7–10—Alabama-Mississippi Section, at Montgomery, Ala. Secretary, Hugh L. Burns, Wholesale Supply Co., 828 S. State St., Jackson, Miss.

Oct. 14–17—Southwest Section, at Texas Hotel, Fort Worth, Tex. Secretary, L. A. Jackson, Mgr.-Engr., Munic. Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 17–19—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, Wilbur E. Bjork, Service Supt., Water Works, 1003 Locust St., Des Moines.

Oct. 24–26—California Section, at Civic Auditorium & Miramar Hotel, Santa Monica. Secretary, John E. Skelton, Exec. Vice-Pres., San Gabriel Valley Water Co., 11142 Garvey Ave., El Monte.

Oct. 29–31—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Harrison F. Kepner, Vice-Pres., Dana Kepner Co., 550 Alcott, Denver, Colo.

Oct. 30–Nov. 2—Ohio Section, at Netherland-Hilton Hotel, Cincinnati. Secretary, M. W. Tatlock, San. Engr., Ralph L. Woolpert Co., 360 W. 1st St., Dayton.

Oct. 31–Nov. 2—Chesapeake Section, at Dupont Hotel, Wilmington, Del. Secretary, Carl J. Lauter, 6955—33rd St., N. W., Washington 15, D.C.

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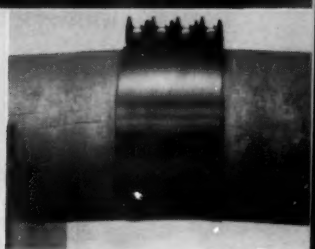

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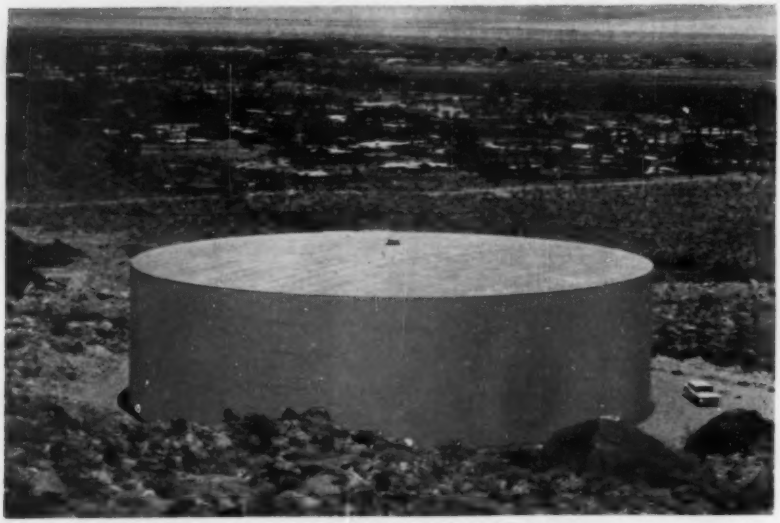

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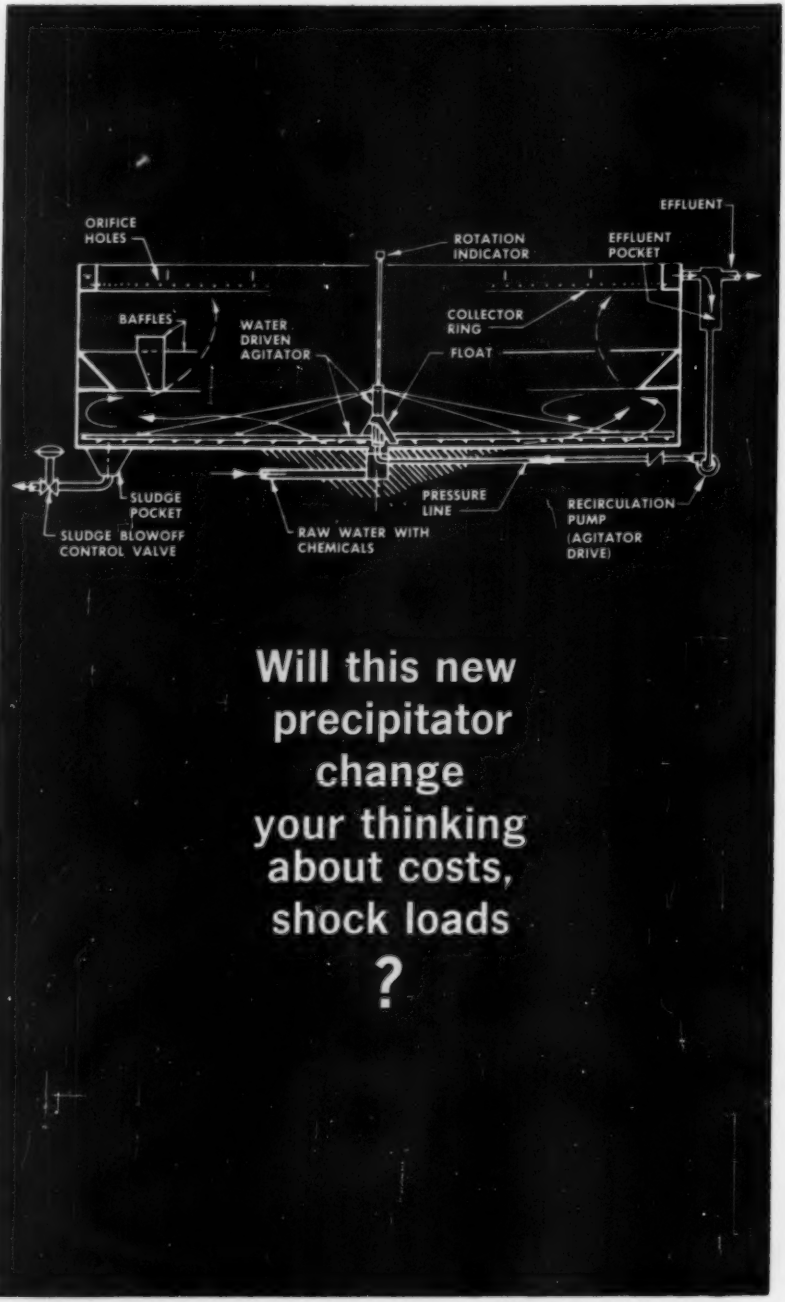
Vannes Darling-France, 23 rue du Commandant Mouchotte, St. Mandé, France

GATE • BUTTERFLY • CHECK • SPECIAL VALVES • FIRE HYDRANTS

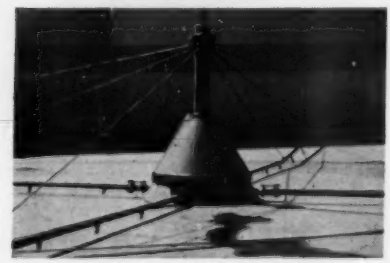

ORIFICE HOLES
ROTATION INDICATOR
EFFLUENT POCKET
EFFLUENT
BAFFLES
WATER DRIVEN AGITATOR
COLLECTOR RING
FLOAT
SLUDGE POCKET
SLUDGE BLOWOFF CONTROL VALVE
RAW WATER WITH CHEMICALS
PRESSURE LINE
RECIRCULATION PUMP (AGITATOR DRIVE)
Will this new precipitator change your thinking about costs, shock loads ?

New Permutit Type M Precipitator ... a study in simplicity

Now in operation is this new precipitator for reducing turbidity and color in water.

We call it the Permutit Type M Precipitator. It is a study in simplicity, and because of its low construction and operating costs, it opens up new opportunities to obtain solids-contact clarification at minimum cost.

"Missing" parts: There is no motor-driven agitator on the Permutit Type M Precipitator. No extensive baffling. No center platform. No access walkway. All these have been done away with, because the unit has a new and different agitator system which sweeps away the settled sludge. Rotating agitator arms are supported by a "semi-buoyant" hub (or float) which revolves about a bearing post on the tank floor. Recycled effluent drives the agitator through jet nozzles located at the end of each arm. Smaller jets, spaced along the arms, gently nudge the settled sludge toward a sump at the outer rim of the tank floor.



Agitator float and hub assembly.

Briefly, this is how the M unit works: raw water and chemicals are mixed in line and enter at the center of the tank floor beneath the conical rotor float which deflects the fluid mixture radially outward to the walls. A horizontal baffle on the tank wall then reverses the flow back toward the center thus imparting a rolling action to the sludge blanket. This current flow constantly places previously formed sludge in intimate mixture with the raw water immediately as it enters the tank. Clarified, effluent is collected by a flume at the top.

Sudden water changes: An additional benefit of the Permutit Type M Precipitator is its exceptional ability to handle shock loads.

A case in point: red dye from a paper mill a mile upstream showed up one day in the raw water entering a Permutit Type M Precipitator in use in New England. But the unit went right on putting out an effluent with no significant change in quality.

So much interest has been shown in this new unit that we have reprinted the paper, "A Recent Development in Solids Contact Clarification Design", by E. D. Driscoll of Permutit. We'll be glad to send you a copy.

Write to Permutit Division, Dept. JA-81, 50 West 44th St., New York 36, New York. (In Canada, contact the Permutit Company of Canada, Toronto.)

PFAUDLER PERMUTIT INC.
Specialists in FLUIDICS ... the science of fluid processes

Offices in principal cities

Split case or frost proof

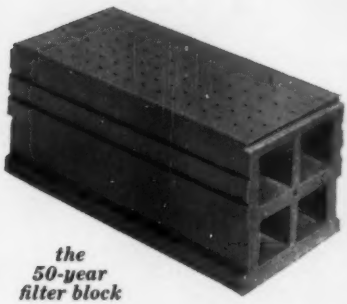
GAMON METER DIVISION

NEWARK NEW JERSEY

WORTHINGTON

WILL TUBERCULATION CLOG YOUR FILTER BOTTOMS?

It can't happen with Leopold Glazed Tile Blocks



the 50-year filter block

Banish concern for tubercular growth when you install Leopold . . . the 50-year glazed tile filter bottoms. The smooth surface of Leopold blocks offers no toe-hold for growth that restricts filtration and wash distribution. Individual Leopold blocks can't corrode or absorb water either, and they're acid and alkali resistant. Performance-proved in over 500 plants throughout the country, both for new and for rehabilitation projects, they require no supporting concrete structures and need only a shallow depth of small-sized filter gravel. Specify Leopold for long-term economy and minimum media maintenance. Write today for facts and figures.

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Zelienople, Pa.
Canadian Representative:
Fielding-Crossman & Assoc. Ltd.
469 Manor Road East
Toronto 7, Ontario

F. B. LEOPOLD CO., INC.
Zelienople, Pa.

☐ Please send literature on Leopold Glazed Tile Filter Bottoms.

☐ Please send literature on complete line of Leopoid products.

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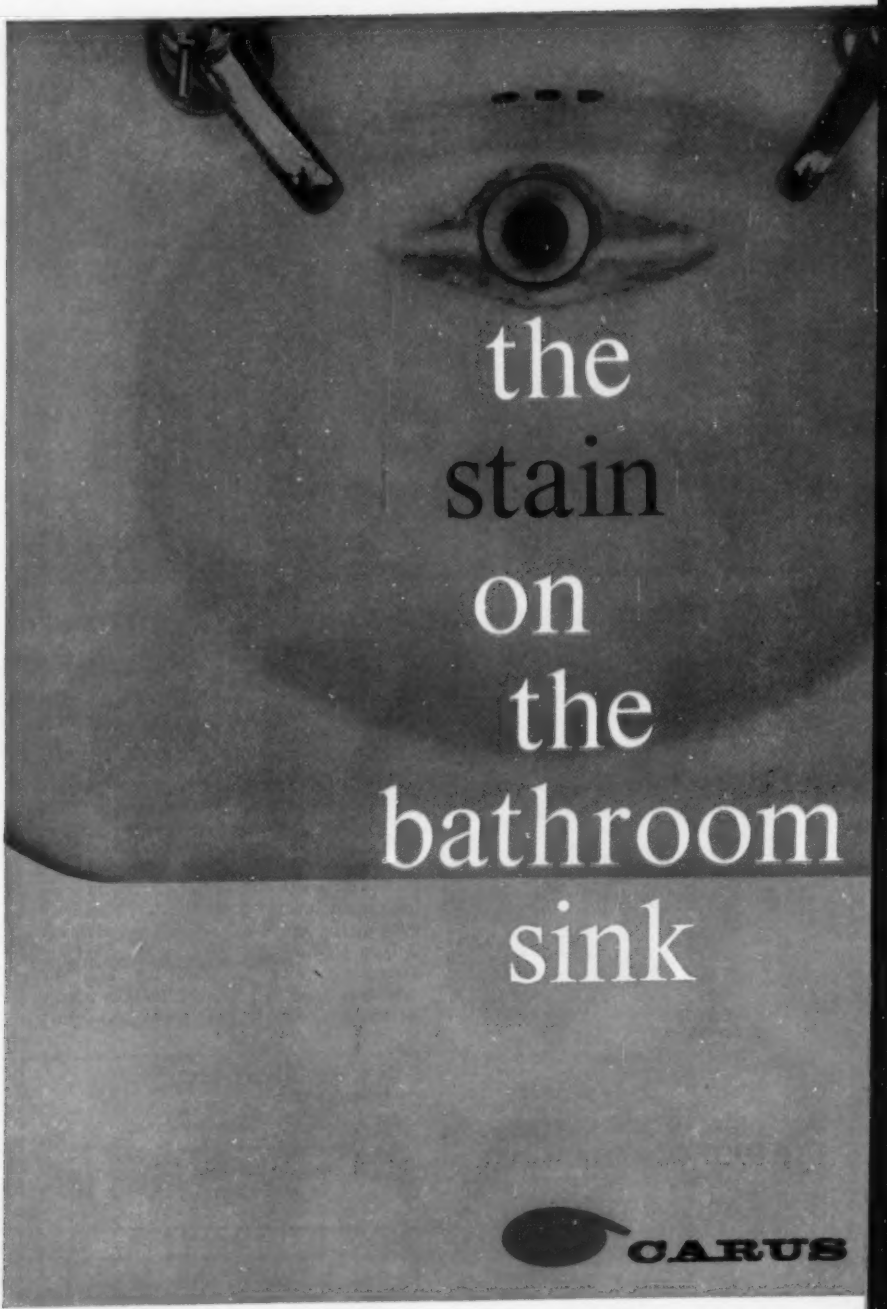
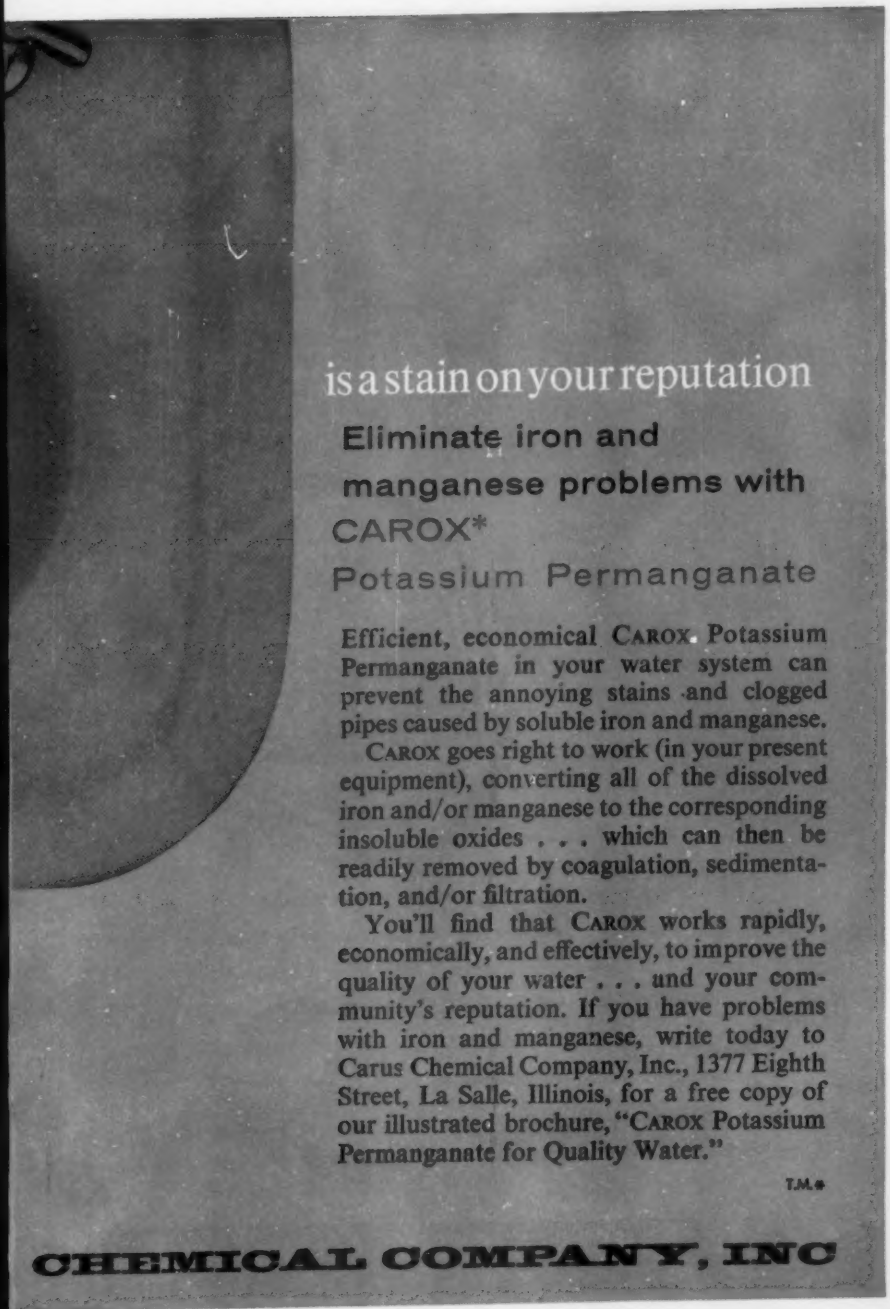

the
stain
on
the
bathroom
sink
CARUS


is a stain on your reputation
Eliminate iron and
manganese problems with
CAROX*
Potassium Permanganate
Efficient, economical CAROX Potassium Permanganate in your water system can prevent the annoying stains and clogged pipes caused by soluble iron and manganese.
CAROX goes right to work (in your present equipment), converting all of the dissolved iron and/or manganese to the corresponding insoluble oxides . . . which can then be readily removed by coagulation, sedimentation, and/or filtration.
You'll find that CAROX works rapidly, economically, and effectively, to improve the quality of your water . . . and your community's reputation. If you have problems with iron and manganese, write today to Carus Chemical Company, Inc., 1377 Eighth Street, La Salle, Illinois, for a free copy of our illustrated brochure, "CAROX Potassium Permanganate for Quality Water."
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Ferri-Floc, a superior coagulant, can eliminate your water purification problems—Coagulation, softening, removal of iron and manganese and other problems encountered in water purification. Our consultants are thoroughly qualified to assist you in producing purer water and would be pleased to come to your plant.

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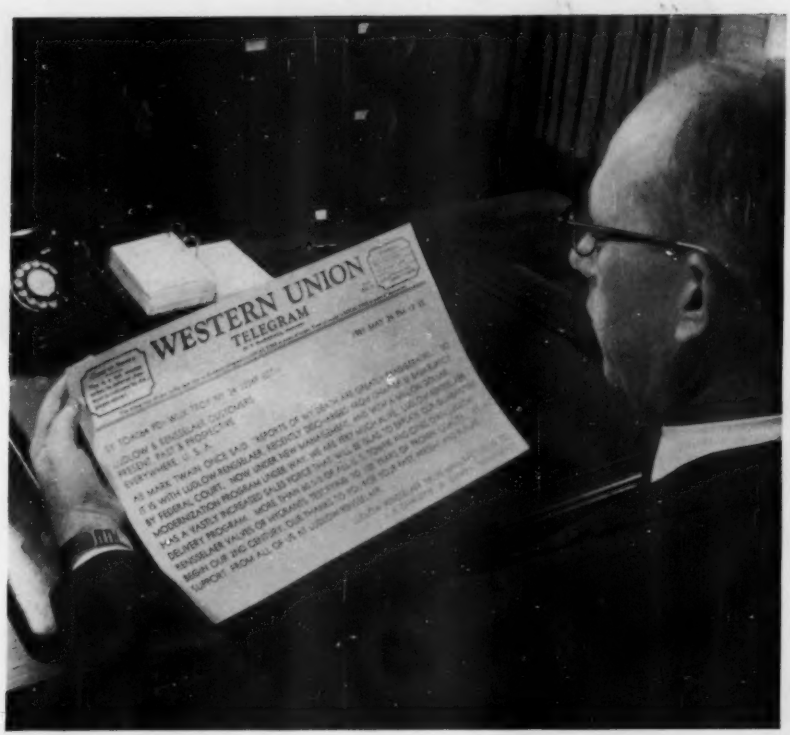
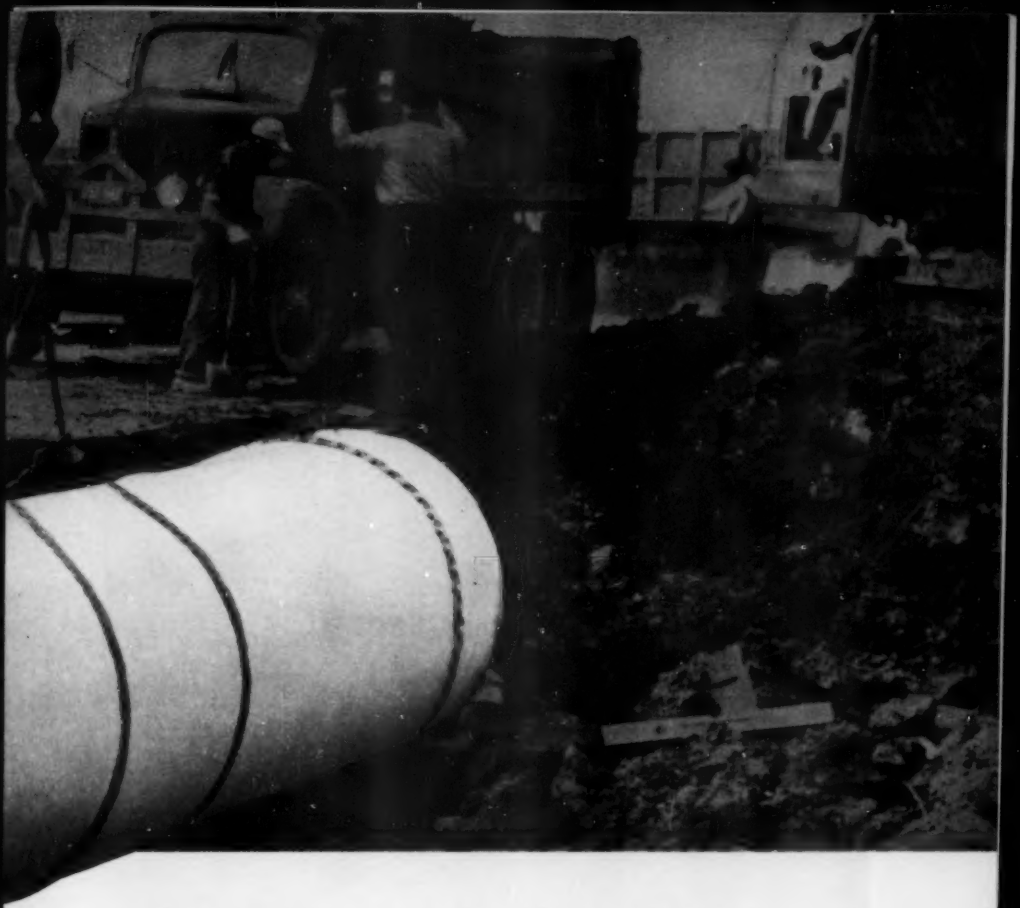
612-629 GRANT BUILDING, ATLANTA 3, GEORGIA



Yes, the rumors of our death *were* greatly exaggerated. LUDLOW-RENSSELAER begins its second century with a new life, a new outlook. Our guaranteed delivery program is only a part of the million dollar physical and mental modernization program now under way. The quality, the durability, the dependability, and the famous LUDLOW-RENSSELAER craftsmanship are still the hallmark of our products. This quality coupled with modern business methods and management is your assurance of excellence.

LUDLOW
RENSSELAER
VALVE MANUFACTURING CO., INC.
TROY, NEW YORK



FORCE MAINS...
critical link in sewer systems

The collection and treatment of sewage often requires pumping through force mains in various parts of the system. No other method of piping for force mains offers the many advantages provided by Concrete Pressure Pipe.

Dense, impervious . . . smooth of interior . . . Concrete Pressure Pipe has excellent hydraulic properties. This means low pumping costs that stay low over the long life of the installation. Little or no maintenance is required. Pipe joints are formed to close tolerances, sealed with watertight yet flexible rubber gaskets, and are easily assembled. Concrete Pressure Pipe can be designed for a wide combination of external loads and internal pressures.

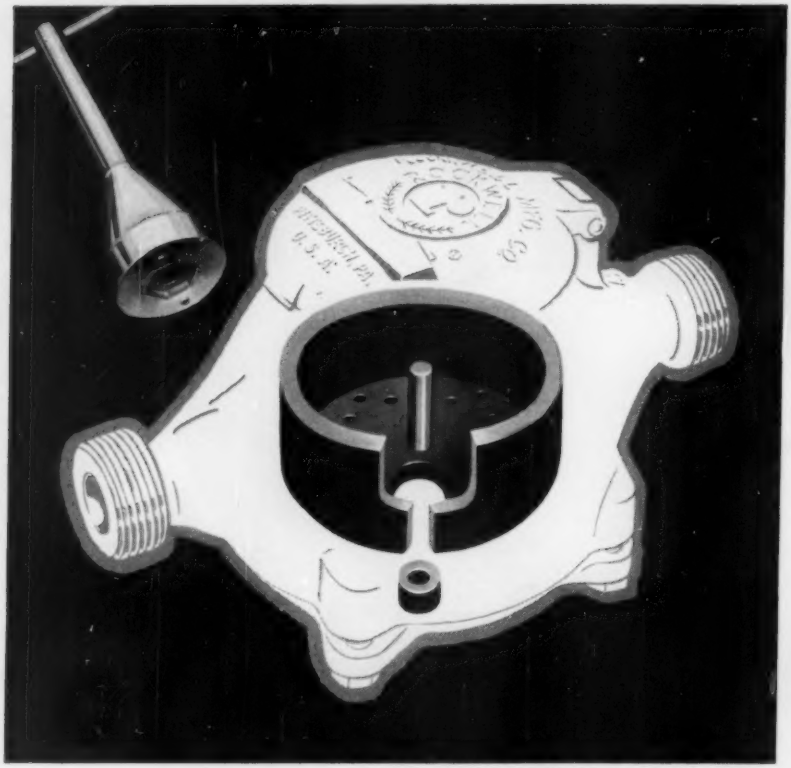
If your city is one of the many requiring sewer system expansion, investigate Concrete Pressure Pipe. It will save you money now and for years to come.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 North LaSalle Street • Chicago 1, Illinois



Only 2 Working Parts and a Wrench

YOU ASKED FOR IT!

Early in the development of our Sealed Register* "magnetic" meter, one thing became apparent. *This design would practically put us out of the parts business.*

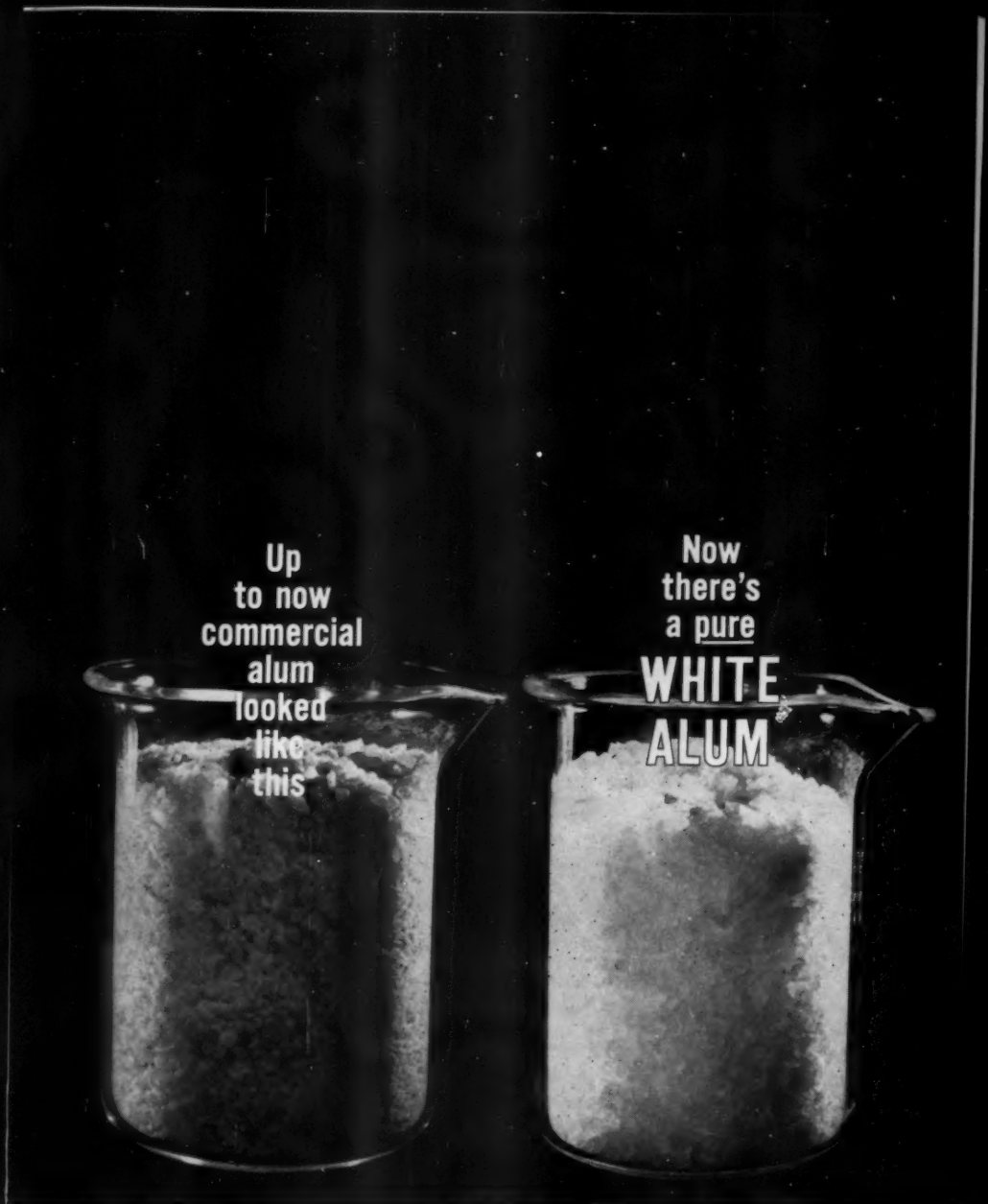
But we went ahead because our surveys showed you wanted a meter with fewer parts and one that would be easier and more economical to repair.

Now you can benefit from a *two part inventory.* A wrench is the only tool required. Let our representative prove this to you or write for bulletin W-811. Rockwell Manufacturing Company, Dept. 163M, Pittsburgh 8, Pa. In Canada, Rockwell Manufacturing Company of Canada, Ltd., Box 420, Guelph, Ontario.

**Trademark*

Imitated but never equalled

SEALED REGISTER* METERS
another fine product by
ROCKWELL



We will be glad to send you a sample of the very first pure white aluminum sulfate available for water and waste treatment. ■ Produced through a dramatic new process by the Chemical Division of The North American Coal Corporation, Miral pure white alum will meet your most rigid requirements, and more. It is uniform in quality and particle size. ■ As a new supplier of high quality alum, we are now offering Miral white alum in bags or bulk, or as liquid alum in tank trucks or tank cars, with rapid and reliable delivery assured. ■ Write today for your free sample of remarkable new Miral white alum. **Offices:** 12800 Shaker Boulevard, Cleveland 20, Ohio. **Plant:** Powhatan Point, Ohio.

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Chemical Division
THE NORTH AMERICAN COAL CORPORATION

U.S. cast iron PIPE FOR WATER, SEWERAGE A

a honey to handle

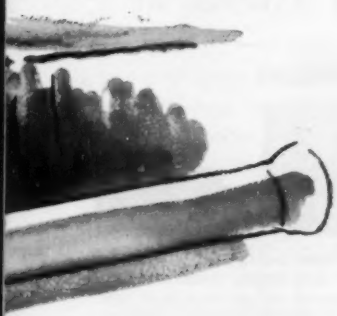
Tyton Joint® pipe, naturally . . .

This rugged dependable pipe goes together so easily even green crews become experts quickly. Consider:

Only one accessory needed—a rubber gasket. No nuts, bolts, bell holes, caulking equipment. And Tyton can be laid in rain or wet trench when necessary.

High installation costs crowding your budget? Get the time-and-money-saving facts on Tyton Joint* pipe today. Call or write:

*U. S. Patent No. 2,953,399



U. S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama

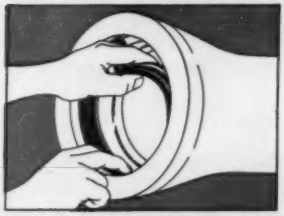
A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe.

Makers of USIFLEX® Boltless Flexible Joint Pipe.

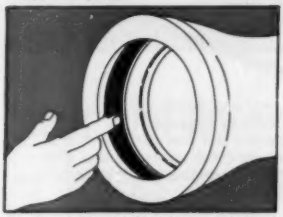
DUSTRIAL SERVICE CAST IRON

TYTON®

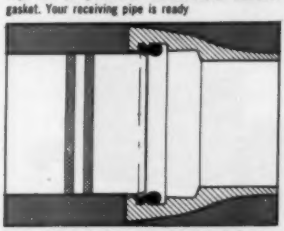
ONLY FOUR SIMPLE ACTIONS



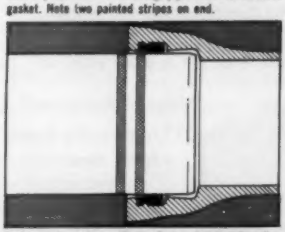
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . bottle-tight, permanently! The job's done . . . fast, efficiently, economically. Could anything be simpler?

Protective Coating Inspection Problems?

Here's Your Answer

No matter whether you're coating a pipeline or a water tank, continuity is vital. Use of a Tinker and Rasor Holiday Detector while the job is open, can save days of downtime later on.

• THIN FILM

Tinker and Rasor
M-1 Holiday Detector

For painted or sprayed thin film coatings such as vinyls and epoxies. Maximum applied voltage 67½ V., non-destructive to coatings. Belt mounted, 4-lbs. total weight.

• PIPE

Tinker and Rasor
E-P or E-4 Holiday Detectors

Output adjustable from 5,000 to 20,000 pulsating voltage.

E-P — All purpose for larger diameter pipe, damp or dry climate, pre-fab film or hot applied coatings.

E-4 — Lower cost, dry surface type of detector specifically designed for smaller diameter pipe and flat surfaces.

• PLANT AND YARDS

Tinker and Rasor
EPAC Holiday Detector

EPAC operates off 110 volts A.C. power for stationary coating operations. Internal voltage adjustment from 5,000 to 20,000 volts or with external variable transformer from 500 to 6,000 volts, or 5 KV to 20 KV.

• UNDERGROUND

Tinker and Rasor
Pearson-type Holiday Detector

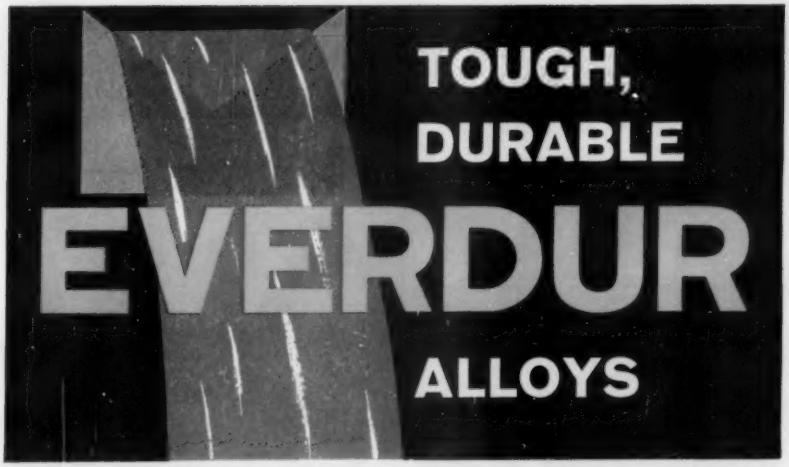
For detecting holidays and electrical shorts without uncovering the pipeline. Completely transistorized . . . generates 15 watt, 750 cycle, stable A.C. Audio-frequency signal. Adaptable to null search method.

Tinker and Rasor has prepared a complete data kit which describes the null search system as well as other recommended procedures for inspecting protective coatings. Material includes technical data on equipment, general discussion of types of detectors, theory of operations, etc.

Quality Control for Coating Application

TINKER & RASOR

417 Agostino Road, Dept. 12-T, P.O. Box 281 • San Gabriel, California



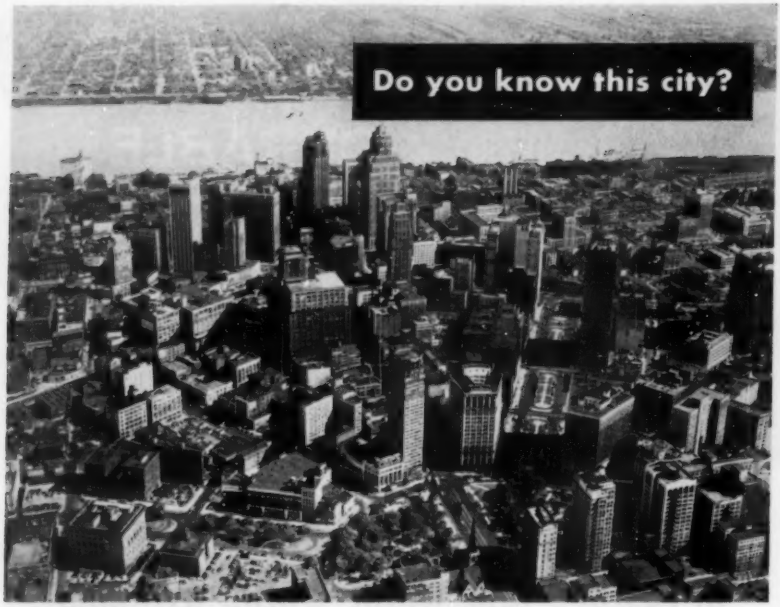
highly resistant to wear and abrasion in sewage and water works systems

EVERDUR® copper-silicon alloys have excellent resistance to corrosion in all types of water works installations and at all stages of sewage treatment operations. EVERDUR equipment in the United States has been in service *without replacement* for 30 years and longer.

Easily fabricated EVERDUR provides high physical strength with lighter weight. It is used extensively in sewage systems handling corrosive wastes in screens, stems, manhole steps, guides, bolts, weirs, float chambers, troughs. And for water works equipment you will find EVERDUR alloys in long service as surface reservoir outlet screens and screen frames and as large diameter cylindrical well screens in drilled well supply systems. Other uses: spillway fittings, guides, seats and sealing strips. And don't forget EVERDUR Electrical Conduit for use in corrosive atmospheres.

Publication E-11 shows typical applications and other data. Write for your copy—or for assistance from our Metallurgical Dept. in selecting the proper corrosion-resistant alloys for your equipment. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Canada. 61-811

EVERDUR®
a product of
ANACONDA®
AMERICAN BRASS COMPANY



DE LAVAL *water works pumps*

maintain vital water requirements of...

Detroit... this vast industrial metropolis depends on De Laval water works pumps to help maintain its high standards of public service. These centrifugal units have given excellent performance in year-round service.

Today, in fact, the great majority of American cities use De Laval centrifugal pumps. Their design and manufacture are the result of 60 years of experience. Units ranging up to 100 million gallons per day are available to meet all water works requirements.

Write for your copies of De Laval Bulletins 1004 and 1005 giving data on these pumps.

De Laval Steam Turbine Co., Trenton 2, New Jersey

PC-DL-100 A

DE LAVAL • 60 YEARS OF CREATIVITY AND QUALITY

CENTRIFUGAL PUMPS AND COMPRESSORS • TURBINES • IMO® ROTARY PUMPS AND HYDRAULIC MOTORS
MARINE PROPULSION AND AUXILIARY EQUIPMENT • HELICAL AND EPICYCLIC GEARS • TURBOCHARGERS

AMERICAN Water Meters

Just one QUALITY...*the Finest!*

Smallest American Meter, 5/8" x 1/2" . . . largest, the 6" Heavy Duty Meter. Solid Casing and Frost Bottom types . . . capacities from 20 GPM to 1000 GPM — to meet every water requirement. Add to this large range in sizes, the most complete design flexibility of any meter and you have the reason why so many water utilities specify AMERICAN.

Every AMERICAN Meter, regardless of SIZE, has the basic, built-in features of unmatched construction simplicity, unequalled measuring accuracy, and the widest range of parts interchangeability.

Every AMERICAN Meter is a measuring instrument of the highest quality, built to last longer, with the least maintenance; to provide greater earnings and better public relations.

Subsidiary of AMERICAN METER COMPANY

For complete details, write for Bulletin 58

BUFFALO METER COMPANY, INC.

Dept. AW, 2917 Main Street • Buffalo 14, N. Y.
300 North Gilbert Avenue • Fullerton, Calif.

Sales representatives throughout the nation

ACCP* BRINGS ABUNDANT GOOD WATER TO CARLSBAD FROM ANCIENT DESERT REEF

...OPENS WAY FOR 50 YEARS OF INDUSTRIAL GROWTH!

MAIN TRANSMISSION LINE of 33" American Concrete Cylinder Pipe extends 33,000 feet northward toward Carlsbad, just below the horizon. Portions of well-collector lines radiate from one of seven automatic pumping stations (white spot in center).

CREW PRECISELY ALIGNS 32-ft. lengths of 24" American Concrete Cylinder Pipe before joining sections. Installation of the 110,000 feet of gathering and transmission lines was completed substantially ahead of schedule.

PIPE LAYING CRANE easily and quickly joins spigot end of ACCP with bell end of previously laid section.

The City of Carlsbad, New Mexico has taken dramatic steps to meet the challenge of today before it becomes the problem of tomorrow. It can now boast a water system that will meet anticipated growth of industry and populace for the next fifty years without need for enlargement. This progressive city of 27,000 has wisely invested $2,500,000 to bring high quality water through a permanent pipeline system from a 200,000,000-year-old sandstone reef located seven miles away. Capitan Reef accumulates an estimated 60,000 acre-feet of natural recharge annually... clean, relatively soft water that will encourage industrial expansion.

The new pipeline system was specifically planned for the future, with 14" to 36" American Concrete Cylinder Pipe specified for all gathering and transmission lines. Although designed for gravity flow up to 32,000 gpm, the 150 psi line can be fully pressurized for substantially greater discharge whenever the City's growth warrants. It will never create a bottleneck in Carlsbad's water supply program!

In your plans for the future of your community, it will pay you to consult American Pipe and Construction Co., manufacturers of modern pipe for man's most ancient problem: WATER.

*AMERICAN CONCRETE CYLINDER PIPE

AMERICAN PIPE AND CONSTRUCTION CO.

LOS ANGELES • SAN DIEGO • HAYWARD • PORTLAND • BOGOTA, COLUMBIA
AMERICAN CONCRETE PIPE CO. • PHOENIX • ALBUQUERQUE
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A MEMBER OF THE AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

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DRY—more uniform particle size, less dust
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General Chemical's dry aluminum sulfate is distinguished by its uniformity of particle size and low dust content. Our liquid alum is low in color, insoluble matter and iron content.

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GENERAL CHEMICAL DIVISION
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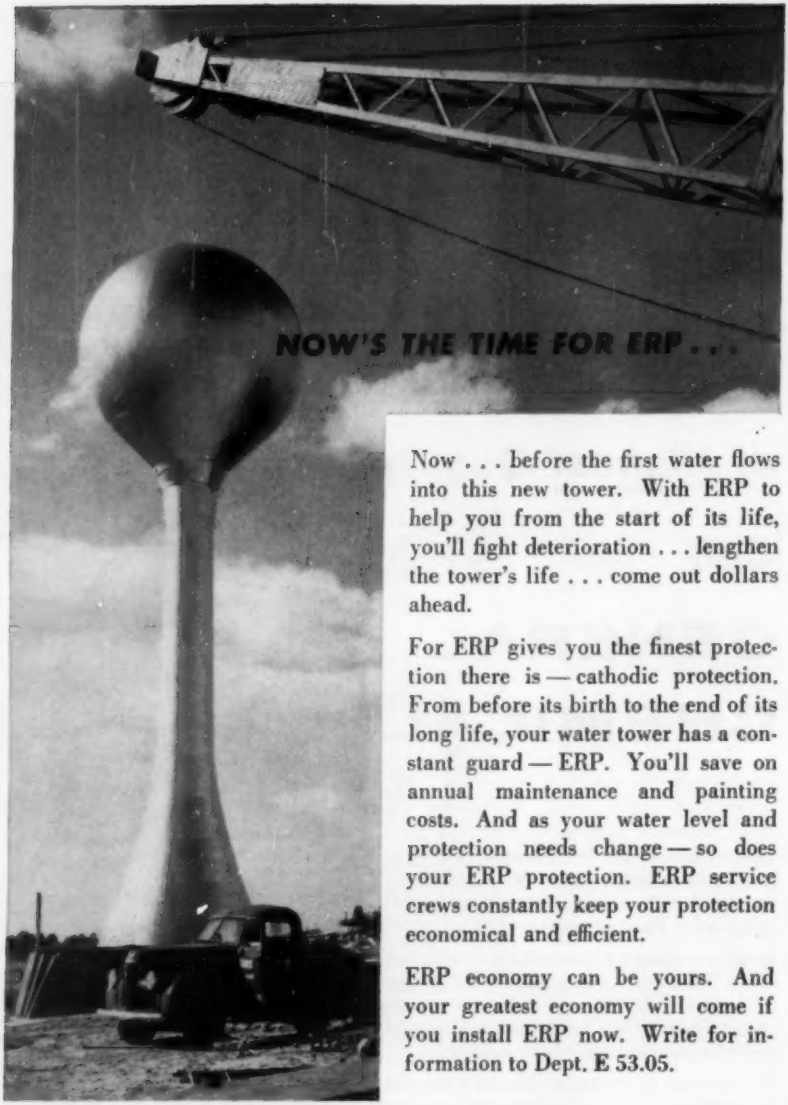

Now . . . before the first water flows into this new tower. With ERP to help you from the start of its life, you'll fight deterioration . . . lengthen the tower's life . . . come out dollars ahead.

For ERP gives you the finest protection there is — cathodic protection. From before its birth to the end of its long life, your water tower has a constant guard — ERP. You'll save on annual maintenance and painting costs. And as your water level and protection needs change — so does your ERP protection. ERP service crews constantly keep your protection economical and efficient.

ERP economy can be yours. And your greatest economy will come if you install ERP now. Write for information to Dept. E 53.05.

ERP
CATHODIC PROTECTION
SINCE 1935

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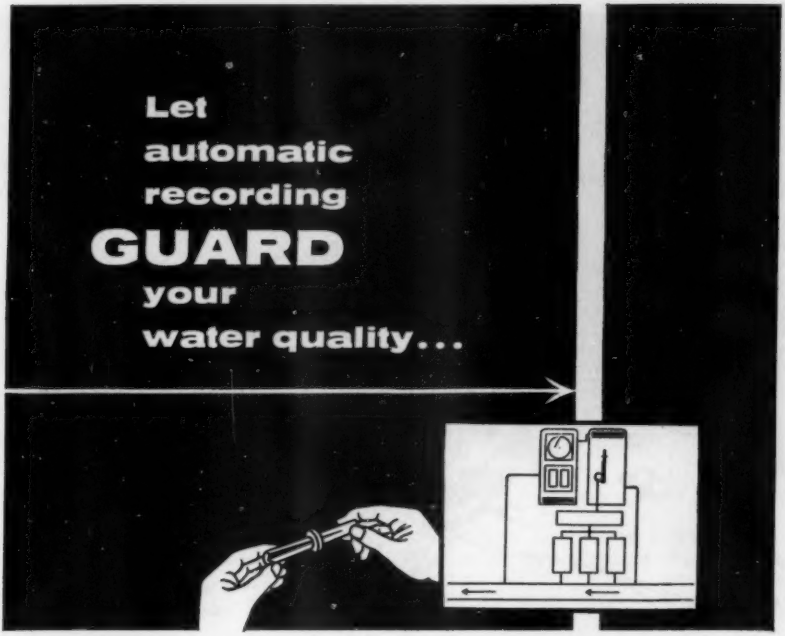
A SUBSIDIARY OF WALLACE & TIERNAN INC.
30 MAIN STREET, BELLEVILLE 9, NEW JERSEY
CABLE: ELECTRO, NEWARK, N. J.



W&T **RESIDUAL CHLORINATION SYSTEMS**

Automatic residual recording by Wallace & Tiernan gives you a finger on the pulse of your chlorination operation. Your system's performance is analyzed; the results recorded accurately. You have an eye on water quality.

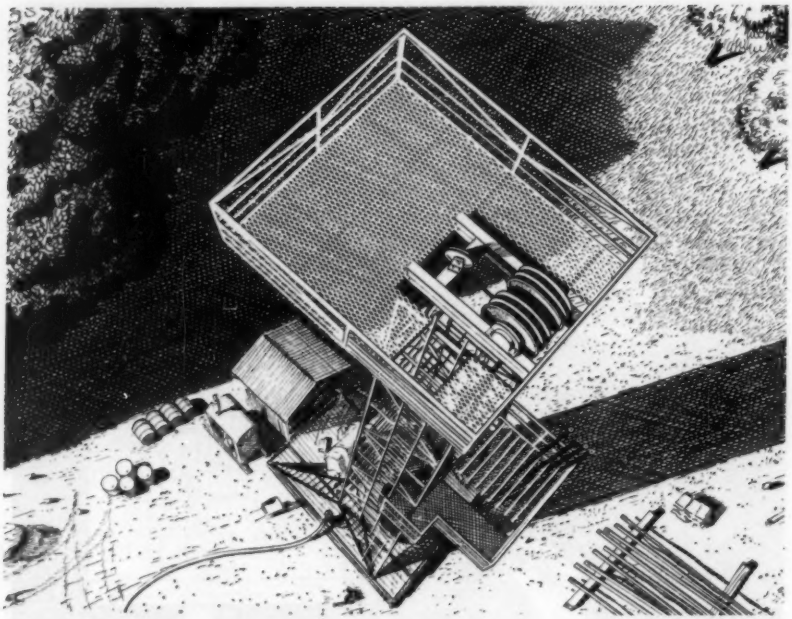
Accurate minute-to-minute records guide plant operation . . . furnish proof of your water's safety. You can analyze your operation and work out efficient maintenance and supervisory routines.

And a W&T Automatic Residual System opens the door to complete automation. You have the basis for Compound-loop Control, the ultimate in chlorination automation.

You can build Compound-loop Control component by component. As the future demands, you can add W&T auxiliary equipment to achieve this closed-loop, information-feedback system, no matter what your present arrangement.

For more information, write Dept. S-140.05

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY



RIGHT...from the top down

A good, dependable water supply system is no better than its beginning. The best beginning is a Layne drilled water well. Layne is the largest water well drilling organization in the world with over 75 years experience. Trained crews operate over 500 drilling and service rigs throughout the country.

Layne service doesn't stop there. A dependable Layne Pump specially designed for the job to deliver a specified QUANTITY of water, and Layne water treatment service to supply the exact QUALITY of water desired, are part of a complete job with undivided responsibility. But, that's not all. Layne maintenance and repair service wraps up the complete package. Your nearby Layne Company is as close as your telephone, so, call on Layne for a dependable water supply, right . . . . . from the top down, all backed by Layne Research.

Layne **WELL DRILLING**

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LAYNE & BOWLER, INC., MEMPHIS

Offices and Factory, Memphis 8, Tennessee

Water Wells • Vertical Turbine Pumps • Water Treatment

Journal

AMERICAN WATER WORKS ASSOCIATION

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Pressure Zoning and Maintenance in the Los Angeles Distribution System

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DIFFERENT regions of the United States have water problems peculiar to themselves. Just as large areas of the East and South have serious sanitation problems in their water supplies, so the Southwest has a characteristic problem, the irregularity and insufficiency of the natural water supply through rainfall. Not only does most of each year's annual precipitation fall in the winter months, but there is also a vast difference in the amount of annual rainfall from year to year. This seasonal and annual variation of rainfall in the Southwest has necessitated the building of many large storage reservoirs and two major aqueducts.

The growth and development of Los Angeles in the semiarid West to a present population of 2,500,000 and an area of 458 sq mi has given rise to a water system with a large number of seasonal regulating reservoirs and one major aqueduct. There are presently seven reservoirs with a total capacity of 350,683 acre-ft along the aqueduct, and 39 reservoirs with a total capacity of 55,594 acre-ft in the city. The city has three major sources of supply: local ground water, Owens Valley water through the Los Angeles Aqueduct, and Colorado River water from the Metropolitan Water District (MWD) (Fig. 1). These sources supplied 21, 62, and 17 per cent, respectively, of the 1959–60 total consumption. It is estimated that with the city's supplies at full capacity and with a full entitlement to MWD water, Los Angeles will have sufficient water to satisfy future growth until 1990. The water system is presently supplying 463 mgd (715 cfs) annually to areas ranging from sea level to 2,440 ft, and has 94 reservoirs and tanks,

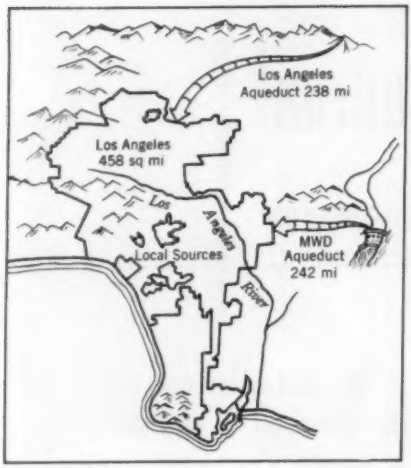

Fig. 1. Sources of Water Supply, 1959–60

The Los Angeles Aqueduct provided 288 mgd, or 62 per cent of the supply; MWD provided 79 mgd, or 17 per cent; and local sources provided 96 mgd, or 21 per cent. Total consumption was 463 mgd.

79 pumping plants, and 185 pressure-reducing regulator stations.

Pressure Zones

The varied topography and allowable pressure range for water systems have required the establishment of over 100 pressure zones which are supplied by gravity water, regulated water, pumped water, or a combination of these sources (Fig. 2). The water system uses a range of 43 psi (100 ft of head) to 100 psi (231 ft of head) for normally operating pressure zones. This range has been sufficient to supply peak consumption and provide adequate fire protection as specified by NBFU and local codes.

Because many of the pump-tank systems in the mountains serve rugged terrain ranging from hilltop to valley, services are sometimes permitted at pressures outside the normal range in order to keep the individual number of pressure zones (and hence pumps, tanks, and pressure-reducing regulator stations) to a minimum. Hilltop developments that require water at sites less than 100 ft in elevation below a tank, and therefore at less than 43 psi, are served only under elevation agreement that limits the water system's responsibility to provide the minimum 43-psi pressure. Hydropneumatic apparatus is used in some pressure zones to provide adequate pressures to small hilltop areas right next to tanks. Developments in valleys near existing pressure zones that

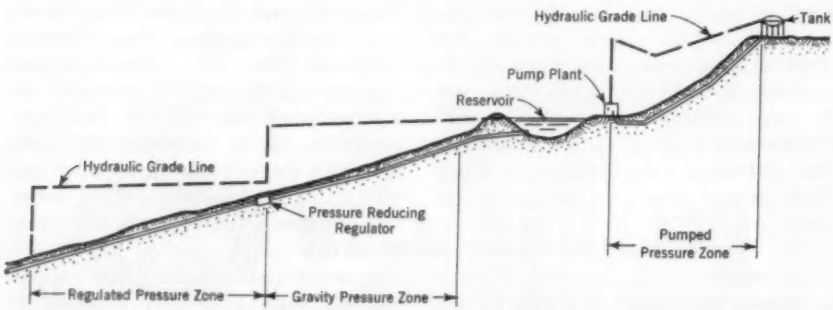

Fig. 2. Pressure Zones Supplied by Regulated, Gravity, and Pumped Water

Normal range for pressure zones is 43–100 psi.

require water at sites greater than 231 ft below a tank are served through individual regulators installed by the consumer to each water service if the pressure exceeds 125 psi.

Regulator Stations

Several pressure zones are supplied by gravity water that is reduced in pressure as pressure-reducing regulator stations at successively lower pressure zones are supplied. The department has 185 of these regulating stations and several flow control stations used to control the rate of flow of water into reservoirs. The size of pressure-reducing regulator stations and flow stations varies widely. Small stations may have 2- and 4-in. regulator valves in parallel legs; larger stations may have an 8-, 12-, and 16-in. valves in parallel legs. The largest valve presently used for flow control and pressure reduction is a 42-in. cone valve.

Flow capacities of regulator stations vary according to the water needed for domestic consumption and fire flow; capacities of flow control stations vary according to quantities needed for filling and operating reservoirs. Downstream systems are protected from excessive pressures caused by regulating valves sticking in an open position by a second regulating valve downstream or by a relief valve where it is possible to spill water in a storm drain or suitable channel. Gate valves are placed on either side of regulating valves to permit repair or replacement.

A unique problem has been encountered in flow control stations using regulator-type valves to control the flow of water, particularly in installations with low downstream pressures. The high velocities produced by throttled valves to control the rate of flow have resulted in a great deal of noise, vibration, and subsequent destruction of lining in the downstream enlarger as the water undergoes reduction in velocity. In Fig. 3 an upstream reducer in which the cement lining is still intact (right), and a downstream enlarger in which noise and vibration have completely torn out the cement lining and have subsequently exposed the metal of the enlarger to the same destructive action are shown. The reducer and enlarger were both replaced after 5 years of service. This destruction is also shown in Fig. 4, in which

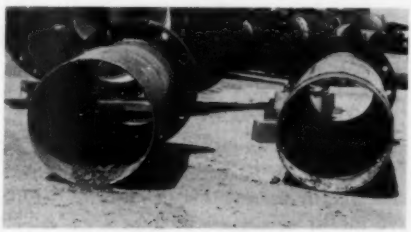

Fig. 3. Downstream Enlarger and Upstream Reducer

Cement lining in downstream enlarger (left) has been destroyed by noise and vibration.

the cement lining in the enlarger has been completely removed except for a small portion at the inlet.

Flow Control Station Design

This noise and vibration have been sufficiently severe to be of considerable discomfort to residents near the flow control stations. In an effort to eliminate the noise, vibration, and damage, very long enlargers were installed in the downstream portion of stations, but with no success. Flow control station designs using straight lengths of pipe connected directly to

flat heads on large-diameter pipe, without the use of reducers or enlargers, have been successful in eliminating this difficulty. A typical installation of this type is shown in Fig. 5, and is referred to as a pressure-reducing manifold with flat heads. A drawing of such a station is shown in Fig. 6.

In traveling from the upstream to the downstream barrel through each leg of the manifold, water undergoes approximately 0.78-velocity head loss at the entrance, friction loss along the length of pipe, 0.1-velocity head loss through each gate valve, and 1-velocity head loss at the exit into the downstream barrel. The station shown in Fig. 6 will have an approximate flow of 10, 20, and 40 cfs in the 6-, 8-, and 12-in. legs respectively, with a 40–60-psi pressure loss across the manifold, and with a limiting velocity of 40 fps in the legs. Pressure differentials in excess of 40–60 psi, which result in velocities in excess of 40–50 fps, have been found undesirable because noise and vibration is set up in the legs. Experiments have been performed at such stations, and the discharge coefficient C in the formula $Q = CA\sqrt{2gh}$—in which Q is flow, A is orifice area, g is acceleration due to gravity, and h is head—has been found to be approximately 0.6.

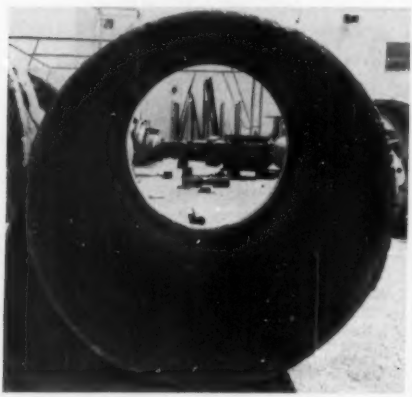

Fig. 4. Downstream Enlarger Stripped of Lining

Concrete lining has been stripped away except for small ring at far end of pipe.

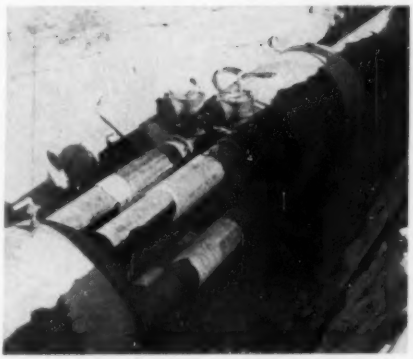

Fig. 5. Pressure-Reducing Manifold

If operated correctly, this pressure reducer eliminates the destructive action of noise and vibration.

The legs are operated either completely open or completely closed, and different amounts of flow are obtained by operating the legs in various combinations. The installation shown, with a 6-in., an 8-in. and two 12-in. legs, will allow a flow of 10–110 cfs in 10-cfs increments. Two gate valves in addition to the operating gate valve are often placed in each leg to allow for repair or replacement of the operating valve without shutting down the entire water main, and valves are encased in a vault to afford accessibility.

Four stations of this type have been installed for flow control purposes, and tests have been conducted to determine their operating characteristics and to eliminate any unexpected prob-

lems. Although it is believed that further investigation concerning the design and operation of these manifolds is necessary, the following general conclusions have been reached as a result of tests and operation:

1. Considerable noise and vibration are encountered in the downstream barrel if the back pressure in the barrel is less than 35 psi. A minimum back pressure of 30–40 psi is assumed in design (Fig. 6). An exception to this has been encountered in one station that has operated satisfactorily with a downstream back pressure of 12–15 psi. In this installation, water discharges into approximately 5,000 ft of 72-in. conduit rather than into a short length (10–15 ft) of large pipe (downstream barrel). It is felt that this long downstream length of large-diameter pipe has accounted for the successful operation at low back pressure and that a relationship exists between the length of the downstream barrel and the minimum back pressure consistent with vibration-free operation. This relationship will probably be determined as more manifold-type installations are designed and tested.

2. Velocities in excess of 40–50 fps, resulting from excessive pressure differential across the manifold, will cause noise and vibration in the legs. A maximum velocity equaling 40–50 fps is used in design, with a maximum of 40–60-psi pressure loss across the manifold.

3. Operating gate valves should be placed as near the downstream ends of legs as possible; if placed in the upstream portions of legs, disturbance through the valve will cause noise and vibration in the pipe during opening and closing of the valve (Fig. 6).

4. In order to eliminate noise and vibration at the leg inlets, it was necessary to project the legs into the barrel and provide relief openings in the projected portion of the legs (detail, Fig. 6).

5. The length of the legs should be a minimum of 20–30 ft in order to

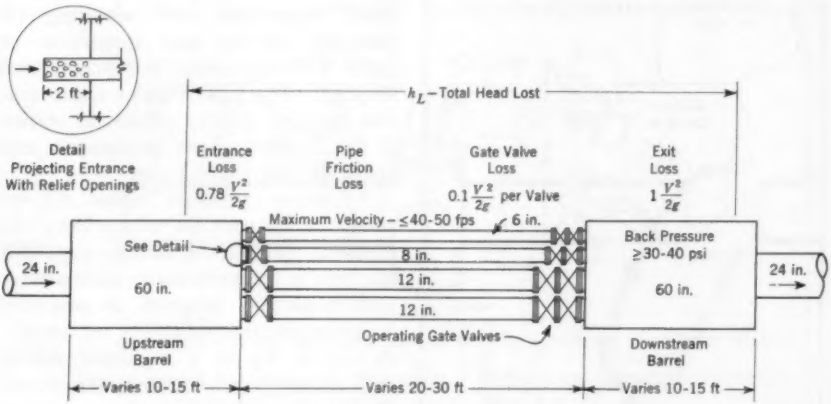

Fig. 6. Manifold-Type Flow Control Station

In the head loss formulas, V is velocity and g is acceleration due to gravity.

stabilize the flow at the higher velocity and to develop sufficient friction loss.

6. Gate valves have been unsatisfactory for frequent operation against large pressure differentials; therefore, cone and spherical valves are being used as the operating valves in the legs. Although the operating valve in each leg is presently operated manually, automatic operation actuated by pressure or flow or by remote control from a central control center is expected in the future.

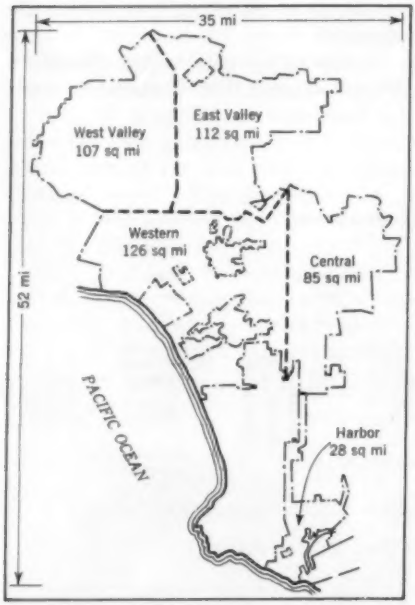

Fig. 7. Los Angeles Water Department District Offices

Maintenance and operation are carried out from the five district offices.

7. Manifold-type regulating stations can be constructed for approximately one-third the cost of valve-type stations because smaller valves can be used and because standard pipe sections can be used in place of specially designed and fabricated reducers, enlargers, and elbows. The manifolds can also be installed in a smaller space, which may result in reduced resurfacing, right-of-way, and vault costs.

Maintenance

Distribution system maintenance includes inspection and maintenance of pressure-reducing regulator stations; testing and servicing of valves; cleaning, cement lining, leak detection, repair, and corrosion prevention of water lines; inspection and servicing of pumping plants; and inspection of dams for alignment, settlement, and seepage. The Los Angeles water system has five district offices, as shown in Fig. 7, from which maintenance and operation are carried out.

As many pressure zones depend solely or in part on water delivered through pressure-reducing regulator stations, a comprehensive maintenance and inspection program is practiced to maintain the reliability of supply. A typical leg of a regulator station and its automatic controls are shown in Fig. 8. Major regulator stations are checked for operation daily and twice a week by a full maintenance crew. Minor regulator stations are visited at least once a week. During the maintenance inspection all parts are checked for normal operation: regulating valves are operated by control of the needle valve, seat and cup leathers are tested for proper seal, needle valves are opened and reset to free any sediment that might restrict flow, the sand trap is cleaned, the relief valve is operated by simulating high pressure, and flow and pressure charts are inspected for correct flow quantities and regulator

operation at desired pressure settings. Any malfunctions discovered are corrected by proper repair or replacement.

All valves in the distribution system are inspected and operated regularly. Gate valves are operated yearly; float-actuated altitude valves on tanks are inspected and operated weekly; and check valves between pressure zones are checked for operation yearly.

The maintenance of water lines consists of cleaning, cement lining, leak detection, repair, and corrosion prevention. Cleaning is done only in conjunction with cement lining because of the rapid rate of tuberculation that follows cleaning only. The majority of cement-lining jobs are initiated because of excessive leak records of water lines; larger water mains are also relined to restore lost capacity and to reduce friction losses. The cement-lining process is usually not attempted if its cost exceeds 60 per cent of a new main installation, in which case it is thought to be more economical to install the new main.

All water lines presently installed are either concrete, asbestos-cement, or cement-lined cast-iron or steel pipe. When external pipe corrosion is discovered, water lines are given cathodic protection by installing magnesium anodes to prevent further deterioration. Flushing of water lines is practiced infrequently to alleviate water quality problems.

Many pressure zones are supplied solely by automatically operated pump-tank systems; therefore, a high degree of reliability must be maintained in all normally operating and standby pumping equipment. All normally operating pumping equipment is powered by electric motors; standby pumping equipment is powered by diesel or gasoline engines. Normally operating maintenance and inspection consist of visits by a pumping plant operator and a senior water works mechanic. An operator visits each plant twice each day and performs a general audio and visual inspection. The plant is checked for adequate operation by inspection of flow and pressure charts for flow quantities and pump operation at desired pressure settings. Any malfunctions discovered by the operator are reported and receive maintenance attention. A senior water works mechanic visits each plant once a week and starts each pumping unit by actuating mercoid controls; the mechanic checks for bearing noise and packing

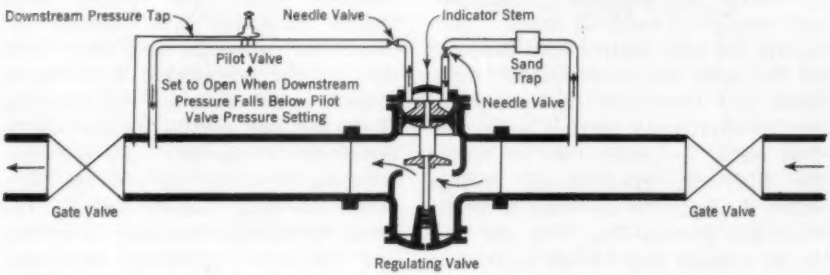

Fig. 8. Automatic Control for Each Leg of Pressure-Reducing Regulator Station

Controls and other components of regulator stations are inspected regularly.

leakage of the pumps, and for bearing noise and excessive dirt or oil in the electric motors. Standby equipment is inspected and operated once a month; standby engines are run once each week.

Electric inspection of pumping plants consists of checking oil and contacts in oil bath starters, testing overload relays by simulating excessive current, and checking the resistance of motor insulation once each six months.

Dam Inspection

Extensive inspection is maintained to observe the alignment, settlement, and seepage of earth-fill dams. Each month, the axis control lines mounted on the dams are surveyed for alignment, and levels are run across the dam to determine if there is settlement. Test wells are maintained to record the hydraulic gradient of seepage water through the dam and to determine soil permeability from the time lag of seepage water levels in relation to reservoir water levels. Seepage through the dam is intercepted in drains and the rate of flow of water measured and recorded weekly. Drains are flushed yearly. Each year water samples are taken from the drains to determine solids content so that the amount and type of material removed from the dam by seepage may be estimated.

If dam cracks are observed, reference points are installed to record possible future movements. In regions of dams that are suspected of moving, tilt measurements are used in conjunction with alignment and settlement measurements to determine the amount and direction of earth movements. All of these measurements are graphed and correlated with past records in order to provide a continuing record of changes and to discover any factors that might cause serious dam failure.

Conclusion

The Los Angeles system is looking forward to increased future use of telemetered and automatically operated facilities, which will provide more flexible operation. It is expected that more flow, pressure, and water level data will be telemetered to a central control center and that all pumping plants and flow control stations will be automatically operated. All pressure-reducing regulator stations are presently operating automatically. The water system will continue to develop and use new operating techniques, equipment, and materials to further increase the efficiency and reliability of service.

Acknowledgments

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Uses of Epoxy Resins

Claud R. Erickson

A paper presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by Claud R. Erickson, Mech. Engr., Board of Water & Light, Lansing, Mich.

READERS of current industrial and trade journals learn that plastics are being used in more and more ways. The many plastic products that have become familiar consist of the principal constituent—the resin or binder—and a filler. The resin or binder is the plastic. The resin is to a plastic article what portland cement and water are to concrete. The resin binder is plastic or moldable at one stage, as is cement paste; but like cement paste, the resin binder sets into a hard mass at a later stage.

Plastic resins are synthetics resulting from the chemical combination of simple compounds into large complex compounds. The variety of plastics thus formed seems limitless, and their physical characteristics vary widely. Their chemical names are enlightening only to the chemist.

One group of plastics, the epoxy resins, shows great promise for the protection of steel and concrete around water facilities. The films of epoxy resins adhere very well to many substrates, such as iron, steel, and concrete, and their films are resistant to chemicals, weather, and water. Most epoxy resins are the result of the chemical reaction of bisphenol A and epichlorohydrin. Through variation of the quantities of these materials or reactants, small epoxy compounds (having low molecular weight) or large epoxy compounds (having high molecular weight) are formed. The low molecular weight compounds are the liquid resins; the high molecular weight compounds, the solid resins.

Classes of Epoxy Coatings

There are two classes of epoxy air-dry coatings on the market. The first contains solvent; the second does not. In the first class are the higher molecular weight epoxy resins. These resins are combined to form three types of coatings—namely, catalyzed epoxy, epoxy ester, and modified epoxy. The first type is the catalyzed epoxy coating, which is a two-package system: one container holds the epoxy resin dissolved in suitable solvents; the other, the catalyst. The catalyst effects the cure of the resin. The second type of coating is the epoxy ester, which is a combination of the higher molecular weight resin and a drying oil acid. This combination is then dissolved in a suitable solvent. The oxidation of the combination cures the coating. The third type of coating is the modified epoxy, which is a combination of epoxy resin and other synthetic resins dissolved in a suitable solvent.

The second class of epoxy coating is the solventless type. It is packaged as a two-component system—one containing the low molecular weight resin,

which is a liquid, the other containing the catalyst. These types of coating are usually referred to as epoxy compounds.

Applications

Industry. Epoxy resins are at present being used mainly in the electrical, aircraft, and plastic-tool industries. The type resins used are the solventless two-component systems, consisting of the low molecular weight resin (liquid) and the catalyst. In 1960, approximately 95 per cent of all plastic tools made were of epoxy resins.

Literature published to date concerning the actual use of epoxies in water treatment industries appears limited. There exists, however, very definite indications that epoxy coatings of all classifications are being used more and more where a coating is needed to protect iron, concrete, wood, and other materials against wear, chemical attack, corrosion, and moisture penetration.

Floor coatings. Epoxy resins of the solvent type, both catalyzed and uncatalyzed, are being used extensively on the floors of hospitals, warehouses, and industrial plants to protect the floors against wear. The epoxy coatings combine the properties of toughness, flexibility, adhesion, and chemical resistance to a degree not found in other coating materials. Furthermore, almost any properties desired or needed in a coating can be obtained by selecting the proper type of epoxy and the proper amount of co-reactants or catalysts.

Concrete repair. A new type of epoxy compound for repairing and resurfacing concrete is being sold. The purpose of this product is to provide a high degree of traction to floors, steps, and walks; to add to the compressive strength of surfaces supporting heavy machinery and subject to heavy usage and traffic; and to impart chemical resistance to surfaces subject to fumes and spillage of acids and alkalies. The compound is supplied with three components—epoxy resin (solventless), converter, and selected sand. When this compound is thoroughly dry, it has twice the compressive strength and triple the tensile strength of concrete. This compound is being used more and more to repair concrete walks and tanks around water plants.

Road repair. The new type of epoxy compound is also being used more frequently in road and highway repairs. Many companies are presently conducting extensive development programs with test strips on bridges and roads. In these tests, the sand component may be replaced with silicon carbide to give better abrasive qualities. The resin component is sometimes modified with tar for desired properties. The solventless epoxy compounds are used as a system for an adhesive or for bonding new concrete to existing concrete.

As these examples indicate, the solventless epoxy resins are rarely used in pure form, because they are many times greater in adhesive strength and chemical resistance than the conventional construction materials with which they are combined. Thus, the resins are compounded with fillers, pigments, high-friction material, and aggregate to produce mixtures appropriate for particular applications.

Water tanks. Protective coatings for steel tanks, including solvent-type epoxy resins, are being tested, as was reported in an article published in a recent issue of the JOURNAL.[1] The article states that although the conventional straight vinyl paint system

gives superior results, as compared to other regularly used types of coatings, its high cost has been a major objection to its use. Poor results were also obtained if too heavy a primer coating was used, or if the primer cover coating was not applied within 2–3 days after the application of the wash primer. The development of a modified epoxy primer vinyl topcoating system [2] has overcome the high cost and other objections to the straight vinyl system. This new system is expected to give even better protection against corrosion than the straight vinyl, because of the superior adhesion and flexibility properties of epoxy.

The interior surfaces of many water tanks have been coated with a modified epoxy system. Inspection of the surfaces, after several years of service, showed this type of coating to be superior to the specification red lead and zinc dust paints and as good as the vinyl system.

Uses at Lansing. The Lansing (Mich.) Board of Water and Light used solventless epoxy compounds, reinforced with fiberglass cloth, to make extensive repairs on a 39-year-old 50,000-gal elevated water storage tank.[3] The board used the solvent compound to paint completely the insides of a chlorine room, the outsides of lime and soda ash slakers, and the outside of several water lines subject to continuous sweating. In all instances, the results have been very good. As of Apr. 26, 1961, two concrete walls of both the No. 4 flocculator and primary settling basins of the water-conditioning plant at Lansing were completely coated with an epoxy primer–vinyl top coat system. Each of these two walls is the outside building wall; any leakage of the lime-treated water through the walls results in discoloration on the outside of the building.

Recreational and other uses. A local manufacturer of epoxy resins, who has to date supplied all types of epoxy coatings and compounds used at the Lansing plant, stated that this type of coating is being used extensively in swimming pools. The use of epoxy in swimming pools has been successful because of the material's amazing affinity, or adhesion, to many substrates, thereby offering a complete water barrier and a high gloss that enhances color seen through water. The company is also manufacturing many types of epoxies for coating premium playground equipment and pedestrian overpasses, for which flexibility of the coating is very necessary; for interior linings for street-flushing tanks; for priming structural steel; and for the coating of steel pickling room walls and floors to protect them against acid and caustic chemicals. Other epoxy products being manufactured by the company are being used as a standard production item in the sealing of weld holes on tubeless tire rims and the painting of trailer homes that will be located primarily in coastal regions where resistance to salt spray and humidity are principal considerations.

Pump maintenance. Solventless epoxy compounds have been used to repair severe erosion and corrosion in eight large circulating water pumps at the Silver Gate Station of the San Diego Gas and Electric Co.[4] Before epoxy was made, spray metal coatings, rubber compounds, neoprene, and ceramics were tried without success. The cost of these repairs was estimated to be $100 per pump, including materials and the labor of two men for half a day. Repair of these pumps

with plastic reinforced with fiberglass fabric allowed salvage of castings that otherwise would have been replaced at an estimated cost of $1,000–$2,500 each. Rogers [4] also explained the manner in which the San Diego company repaired large voids in the wearing rings of the same pump castings and in condenser water boxes. He concluded that if new cast-iron water boxes were factory treated with solventless epoxy resin and glass cloth, they should last indefinitely and require only occasional touchup with the liquid resin to repair worn spots.

Conclusion

Many problems of maintaining water supply facilities can be solved by the use of epoxy resin coatings and compounds. But discretion should be exercised in selecting the type of epoxy coating or compound for a particular application, because a great variety of properties may be obtained by selecting different reactants and catalysts. The life of existing and new structures and equipment can be prolonged, at relatively low cost, by the use of new repair techniques now made possible by these versatile resins. During this period of high costs, the economies to be realized by the use of plastic coatings should be considered by both designers and operators in the water supply field.

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Control of Red Water Due to Pipeline Corrosion

Martin E. Flentje

A paper presented on Oct. 21, 1960, at the New Jersey Section Meeting, Atlantic City, N.J., by Martin E. Flentje, Chief San. Engr., American Water Works Service Co., Philadelphia, Pa.

PRESENT water purification and treatment techniques produce water of excellent physical quality. Even older plants have little trouble turning out water that has very low turbidity, color, and generally a low concentration of taste and odor. Eld and Flentje [1] have shown that an old purification plant dating back to World War I, with inadequate flocculation and filter media of 24-in. depth and less, is able to produce a water meeting industrial standards considerably more stringent than the requirements of water for a public water supply system—that is, iron, 0.02 ppm or less; manganese, 0.005 ppm or less; color, 1.0 ppm or less; turbidity, 0.50 ppm; and filterability, 200 gal at plug point (filterability determined by passing water through a standard glass fiber filter at 50 psi until flow ceases. Number of gallons passing filter is plug point figure).

Maintaining this high quality as the water flows through the distribution system is another matter, and many systems have difficulty doing it. Redwater troubles are not infrequent; black water is the cause for complaints from time to time in many systems; and, in spite of the definite improvements in water treatment and water quality, it is still necessary to flush systems twice a year. In almost every system, certain dead ends must be flushed much more frequently. This article will not discuss all these difficulties, but will offer some data on the control of red water and disturbances in distribution systems caused by surges and higher-than-normal velocities.

Saturation Index

Many years ago, Baylis [2] prepared a graph that gave the relationship between pH, alkalinity, and the zone in which iron stains would occur. These curves have not proved entirely satisfactory because they did not take into account temperature, calcium content, and the total solids content of the water. Later, Langelier [3] published a formula based on physical chemical data for establishing the pH of a particular water at which that water would be in equilibrium with $CaCO_3$. This level was called pH_s. Hoover [4] and others published modifications of the Langelier formula, and today the Langelier $CaCO_3$ saturation index ($pH-pH_s$) is familiar to all water supply people interested in pipeline corrosion problems. This index ($pH-pH_s$) at 0 value indicates a condition at which the water is in equilibrium with calcium carbonate; when in contact with this compound it will neither dissolve it nor precipitate any calcium

TABLE 1

Typical Examples of Systems Studied

Location	pH, at 60°F	Polyphosphate Used	Iron Pickup in System *ppm*	Maximum Iron in System *ppm*	Remarks
Alexandria, Va.	−2.05	no	0.17	0.60	No difficulty in area served by concrete and cement-lined pipe
		yes			In old part of system, trouble even with 3 ppm polyphosphate. Red water prevalent unless residual chlorine kept high
Clinton, Iowa	0.08	yes	0.08	0.15	Red water because of dissolved iron in well water. Polyphosphate added to decrease $CaCO_3$ deposition on valves. Index shows trouble not due to corrosion.
East St. Louis, Ill.	−0.31	no	0.01	0.08	Little trouble
Hopewell, Va.	−1.86	no	0.10	0.20	Trouble at this pH_s, more at pH_s −1.20
Irvington, N. J.	−2.40	yes			Numerous red-water complaints. Application of 3 ppm phosphates helps
Marion, Ohio	0.60	yes			Trouble with sticking valves due to $CaCO_3$
Monmouth, N. J.	−1.18	no	0.03	0.14	Difficulty whenever index drops below −1.25 or system is disturbed
Monongahela, Pa.	−0.14	no			Red water in old tuberculated lines
Noroton, Conn.	−2.38	yes			Numerous complaints until 2 ppm polyphosphates applied
St. Joseph, Mo.	0.29	no	0	0.10	No trouble
South Pittsburgh, Pa.	−1.00	no	0.04	0.05	No difficulty since index raised from former level of −1.8 to −2.0
Uniontown, Pa.	−3.60	yes	0.24	0.35	Complaints when hydrants opened or flow reversed
Westmoreland, County, Pa.	−0.10	no			Trouble only in galvanized, tuberculated lines
White Deer, Pa.	−2.97	no	0.72	1.68	

carbonate from its own chemical content. A positive index indicates a tendency to deposit $CaCO_3$ and a negative value to dissolve $CaCO_3$.

Fortunately, the saturation index ($pH\text{-}pH_s$) is also indirectly an index of corrosiveness. This is true because a practical solution to pipeline corrosion problems involves calcium carbonate. Langelier [3] states:

> Any water, regardless of its composition, after a certain period of contact with a clean iron surface, will cause corrosion of the metal. If, however, certain of the products of the corrosive action are held at the boundary surface, the corrosion rate is reduced, and, if the conditions are favorable, further corrosion will be practically eliminated. The problem therefore resolves itself into one of obtaining a suitable protective coating. . . . In natural oxygen-containing water, calcium carbonate is the salt which is most useful in forming or, together with rust, assisting in the formation of a self-healing or neutral protective coating.

TABLE 2

Langelier Index and Iron Pickup in Distribution Systems

Location	Langelier Index ($pH\text{-}pH_s$) at 60°F	Ryznar[5] Index ($2pH_s\text{-}pH$)	Average Iron Pickup in System—*ppm*	Maximum Iron in System Test—*ppm*
Alexandria, Va.	−2.05	11.10	0.17	0.60
Ashtabula, Ohio	−0.71	8.80	0.15	0.75
Ashtabula, Ohio	−0.59	8.48	0.08	0.30
Bernardsville, N. J.	−0.60	9.50	0	0.09
Chattanooga, Tenn.	−1.24	10.18	0	0.04
Clinton, Iowa	0.08	7.34	0.08	0.15
Davenport, Iowa	−1.01	9.12	0.06	0.10
East St. Louis, Ill.	−0.31	8.02	0.01	0.08
East St. Louis, Ill.	−0.17	7.74	0.03	0.25
Ellwood City, Pa.	−0.13	8.20		
Huntington, W. Va.	0.32	8.26	0	0.10
Monmouth, N. J.	−1.18	10.62	0.03	0.14
Monongahela, Pa.	−0.14	8.70	0	0.12
Muncie, Ind.	0.20	7.30	0.05	0.18
Newark, N. J.	−2.40	11.70		
New Castle, Pa.	−0.57	8.94	0.04	0.07
Noroton, Conn.	−2.38	11.46		
Old Dominion, Va.	−1.86	11.82	0.10	0.20
St. Joseph, Mo.	0	7.70		
St. Joseph, Mo.	0.29	7.22	0	trace
South Pittsburgh, Pa.	−1.00	9.70	0.04	0.05
Uniontown, Pa.	−3.60	13.60	0.24	0.35
Uniontown, Pa.	−2.09	11.09	0.22	0.65
White Deer, Pa.	−2.97	12.94	0.72	1.68

A rust coating not containing $CaCO_3$ is too porous and is not sufficiently dense and continuous to offer protection, and on the contrary, can accelerate corrosion in the form of pitting. Baylis,[4] dealing with the tuberculation and corrosion of pipelines, says almost the same thing. The crust that forms over the surface of the tubercles tends to stop corrosion almost entirely by preventing water from getting to the metal.

It may be assumed, then, that red water is caused by conditions that

prevent deposition of the iron removed from the iron pipe surface through corrosion, or by conditions that prevent rust from depositing with enough adherence to keep it in place under the flow conditions existing in a pipeline. The fact that high flow rates help to accentuate red water conditions is well known to any water utility manager who has had to explain such conditions after a main break or after street-flushing crews have used fire hydrants to fill their tanks.

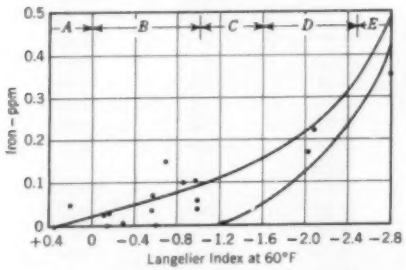

Fig. 1. Langelier Index and Iron Pickup in Distribution Systems

A *is zone of* $CaCO_3$ *deposition;* B, *of little pickup;* C, *of red and dirty water;* D, *of red water unless polyphosphates are used;* E, *of red and dirty water even if polyphosphates are used.*

In water containing CO_2 and having a low pH, the ferrous iron dissolves from the pipe surface and is followed by a reaction between it and the CO_2 to form soluble, colorless ferrous bicarbonate:

$$Fe^{++} + 2H_2CO_3 = Fe(HCO_3)_2 + H_2$$

In most systems, oxygen is present in the water, resulting in an oxidation of the iron compound:

$$4Fe(HCO_3)_2 + 10H_2O + O_2 = 4Fe(OH)_3 + 8H_2CO_3$$

This leaves CO_2 again available to repeat the process.

In this type of water (CO_2 and low pH), oxidation of the ferrous hydroxide takes place in the water, and the red ferric compound is carried along in suspension.

Equilibrium Point

If the pH of this water is raised sufficiently to use up all of the CO_2, the iron removed from the pipe will react with the OH radical of the alkaline water solution to form insoluble ferric hydroxide, $Fe(OH)_3$, in place—that is, attached to the pipe wall. If the water in the main is also at about the equilibrium point, thereby depositing $CaCO_3$, a deposit that is a combination of rust and calcium carbonate will result, a coating that tests have shown is quite adherent to the main.

The $CaCO_3$ equilibrium point is therefore an important value in red-water prevention. The author believes that nearly all red-water problems caused by corrosion of the mains would be solved if it were possible to bring the waters concerned up to or slightly over the $CaCO_3$ equilibrium point. The only exceptions to this conclusion appear to be in water with low alkalinity after pH correction and in water that must travel through badly tuberculated pipe (mains that are old and nearly filled with rust).

Other cases exist where treatment to pH_s is not practical, as in (1) maintaining water supplies fed by gravity into the system where extreme variability of flow and lack of power help make any kind of chemical treatment difficult, (2) naturally soft waters where it seems undesirable to introduce the calcium hardness that is necessary, (3) some filtered waters where introducing sufficient lime to desired

pH increases turbidity to undesirable values, (4) well supplies made up of a number of widely separated wells.

In certain places, the author's experience has also indicated that bringing a water to or above pH_s is not sufficient to prevent red water if there are badly tuberculated mains in the distribution system. Probably this occurs where active tuberculation and pitting is taking place.

In Table 1 and 2, a number of red-water complaint situations have been studied and reviewed in an effort to establish a common factor, if any, that aided in setting up preventive treatment. In addition, samples were collected from the peripheries of the systems to determine the iron pickup as the water traveled the lengths of the pipelines. Some of the systems studied had a record of unstable conditions in which even slight disturbances to the system resulted in dirty water. All of the systems contained old cast-iron pipe that was originally not lined with cement, cement-asbestos pipe, cement-coated cast-iron pipe, and reinforced concrete mains. Since about 1927, all cast-iron mains laid have been cement lined and paint seal coated; in recent years, all concrete and cement-asbestos pipe has also been so protected. For comparison, all pH_s values have been calculated at 60°F.

Discussion

From the results obtained, it appears that red water from corrosion of unlined or unprotected cast-iron mains should not be troublesome—that is, not result in extensive consumer complaints, if the $CaCO_3$ saturation index is maintained within 1.0 unit of saturation (a saturation index up to −1.0). Between an index of about −1.0 and −1.6 red-water complaints can occur. Disturbances noticeable to the consumers due to rapidly opening valves and changes in velocity result in complaints. Waters having a pH-pH_s value below −1.6 can expect red-water trouble. These are general statements to be used as guides rather than specific treatments.

The use of polyphosphates minimizes the need for pH correction considerably. Dosages of 2 ppm or more might be required and, with an index below −2.75, such treatment might not entirely eliminate red water and consumer complaints caused by dirty water.

Figure 1 shows the general relationship between $CaCO_3$ saturation values and iron pickup as found in this investigation.

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Evaluation of Method for Counting Gross Radioactivity in Water

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A contribution to the Journal by J. W. Mullins, Radiochemist, Radiological Health Training Activities, Div. of Radiological Health; R. C. Kroner, In Charge, Service Lab., Water Quality Network, Div. of Water Supply & Pollution Control; D. G. Ballinger, Acting Chief, Analytical Reference Service, Training Program, Div. of Water Supply & Pollution Control; and H. P. Kramer, Chief, Training Program; all of the Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

WITH the growing importance of radiation surveillance programs, public health agencies are increasingly involved in the determination of radioactivity concentrations in the environment, including the monitoring of water supplies. The results yield information of interest to public health. Because of its relative simplicity, the determination of gross activity in water is generally within the capabilities of state and local health department laboratories, permitting the monitoring of public water supplies and the screening of samples. Protection of the public from radioactive materials in water supplies can be said to rest ultimately on the reliability of available data. Accepted standard procedures for the determination of gross radioactivity in water would greatly increase the validity of the data obtained by the laboratories engaged in these determinations.

The evaluation of procedures for laboratory operations is a recognized means of establishing the reliability of analytic data. Exchange of information between laboratories and comparison of results greatly assist such a program. The Robert A. Taft Sanitary Engineering Center at Cincinnati, through its Analytical Reference Servive, has applied itself to the evaluation of laboratory methods and the development of reliable data in the field of sanitary engineering. This is accomplished by the distribution of split samples to member laboratories that report the results of their analyses to the Analytical Reference Service. In 1958, the service began a study of methods for the determination of radioactivity in water.

First Sample

The first sample in the study was prepared to simulate a natural water sample of the type often encountered in routine examination. The sample study was designed to provide answers to these questions:

1. How accurately is radioactivity at normal or background levels being determined?
2. What factors in the analytic procedure affect accuracy?
3. Is there a demonstrable need for standardization of sample preparation and counting techniques?

TABLE 1

Comparison of Laboratory Determinations With Calculated Amount of Activity

Source of Data	Activity $\mu c/ml$
Calculated value	5.44×10^{-7}
Oak Ridge National Laboratory	$5.3\pm0.05\times10^{-7}$
Radiological Health Research Activities*	$5.8\pm0.4\times10^{-7}$
Analytical Reference Service*	$5.6\pm0.1\times10^{-7}$

* Taft Center.

4. Does the type of instrumentation affect the results significantly?

The sample was prepared by adding an accurately measured amount of Tl^{204} to 160 liters of Cincinnati tap water. The thallium was obtained from the National Bureau of Standards, along with a certificate of activity used as the primary standard in calculating the activity added to the sample. To check the accuracy of the calculations, preliminary gross activity determinations were made by three referee laboratories. A comparison of these counts with the calculated amount of activity is shown in Table 1. On the basis of the values in Table 1, the amount of activity in the sample was considered to be 5.44×10^{-7} $\mu c/ml$.

Four-liter aliquots of the sample were distributed to 31 member agencies for analysis. The data from 25 of the 31 laboratories * are summarized in Table 2.

Factors Affecting Results

An evaluation of the laboratory results indicated that overall accuracy and precision were affected by four factors, detailed in Table 3: (1) solids drying temperature, (2) type of counting instrument used, (3) choice and preparation of standard, and (4) sample volume.

On the basis of the information shown in Table 3, it is apparent that the most accurate results were obtained by those laboratories employing a procedure that included the use of: (1) a solids drying temperature of 103–110°C, (2) an internal proportional counter, (3) Tl^{204} as a standard, with self-absorption correction curves prepared by adding the standard to varying amounts of dissolved solids, and (4) a sample of 500 ml or less.

Conclusions From First Sample

Three conclusions were derived from the first sample of the radioactivity study:

1. Half the agencies participating in the study could obtain results within 15 per cent of the true amount of activity in the sample.

TABLE 2

Summary of Data, First Sample

Item	Value
Amount of activity in sample—$\mu c/ml$	5.44×10^{-7}
Amount recovered, all groups, $\bar{x}$—$\mu c/ml$	4.13×10^{-7}
Median—$\mu c/ml$	4.62×10^{-7}
Range—$\mu c/ml$	$(-0.30$ to $+8.20)\times10^{-7}$
No. of results within $\pm10\%$ of true amount	8
No. of results within $\pm50\%$ of true amount	20
Mean deviation from amount added—%	29.9
Standard deviation from mean—$\mu c/ml$	1.84×10^{-7}
Standard deviation from amount added—$\mu c/ml$	2.27×10^{-7}

* Twenty-five agencies returned their results in time to be included in the statistical analysis.

2. A well defined technique, embodying the factors discussed before, is needed to insure satisfactory laboratory performance.

3. The internal proportional counter yields satisfactory results in the average laboratory.

Second Sample

The second sample in the study was designed to evaluate the following factors, determined to be significant as a result of the first sample: (1) a prescribed sample-preparation procedure, (2) the type of counter to be used for beta or gamma counting, (3) preparation of the standard, and (4) the effect of sample thickness (self-absorption).

In the preparation of the second sample, Tl^{204} was considered as a source of radioactivity because of its wide use as a standard for measuring the radioactivity of mixtures of unknown composition. As shown by the data, however, Tl^{204} is volatile, causing significant losses unless the drying temperature is carefully controlled. Furthermore, it is a pure beta emitter, lacking gamma emissions, and its half-life is not well established. For these reasons, Cs^{137} was suggested as a more appropriate standard. In reference samples, this nuclide has the advantage of having a long half-life (30 years) as well as other desirable characteristics. Accordingly, Cs^{137} was selected as the source of activity for the second sample in the radioactivity study.

As before, Cincinnati tap water was used as the sample substrate. To accommodate the large number of participating agencies, it was necessary to prepare 320 liters of the sample. To check the uniformity of distribution of the nuclide in the sample, aliquots were withdrawn from the top, middle, and bottom of the mixing tank and counted for 100 min on a 100-channel analyzer equipped with an inverted well-type beaker over a 4-in. NaI crystal. The results agreed within 2 per cent. The counts were then calculated as gamma activity, expressed as microcuries per milliliter $\times 10^{-7}$. The apparent beta ac-

TABLE 3

Detail of Factors Affecting Results

Factor	Mean Radioactivity $\mu c/ml \times 10^{-7}$
Drying temperature of solids	
> 165°C (4 results)	2.08
< 165°C (22 results)	4.50
Type of counting instrument	
End window (11 results)	3.05
Internal proportional (15 results)	4.91
Choice of standard	
Tl^{204} (10 results)	4.43
Other (16 results)	3.94
Tl^{204} with self-absorption curves (5 results)	5.24
Sample volume	
1.0 liter (6 results)	2.98
0.5 liter (12 results)	3.92
< 0.5 liter (6 results)	5.57

TABLE 4

Standardization of Second Sample

Source of Data	Activity	
	Beta $\mu c/ml$	Gamma $\mu c/ml$
Calculated activity	7.1×10^{-7}	5.3×10^{-7}
Radiologic Health Research Activities*	6.8×10^{-7}	5.1×10^{-7}
Oak Ridge National Laboratory	6.3×10^{-7}	
Average (activity added)	6.7×10^{-7}	5.2×10^{-7}

* Taft Center.

tivity was obtained by multiplying the gamma activity by 1.33. The apparent beta activity, rather than the true beta activity, was used because the activity detected by a beta counter includes conversion electrons from Ba^{137m} * as well as beta particles from Cs^{137}. To referee the sample check described, an aliquot was sent to the Oak Ridge National Laboratory for analysis. Results are shown in Table 4.

The sample was then distributed to 45 participating laboratories, of which 41 returned results. The laboratories were requested to use the following specifications for sample preparation:

1. Volume of sample: 500 ml
2. Evaporation temperature: 95° to 98°C
3. Evaporation container rinse: 0.5 ml of 0.1*N* HCl for aluminum planchets, or 0.5 ml of 0.1*N* HNO_3 for stainless steel planchets
4. Final drying temperature: 105°C for 2 hr
5. Analysis in triplicate.

Results of the second study, for which the above specifications were used, are summarized in Table 5.

As in the first-sample study, the type of instrument used in beta counting was evaluated. The instruments used in the second study and the mean value of the corresponding results are shown in Table 6.

In contrast to the first sample, the data in Table 6 indicate that the end-window counters can be as reliable as the internal proportional counter. As many of these laboratories also participated in the first sample study, and as the importance of positioning was pointed out in the report of that study, the improvement noted may be the result of more careful attention to geometric factors.

* The letter *m* following the mass number of a radionuclide indicates an isomeric state.

Effect of Choice of Beta Standard

The choice of a standard for beta counting was not specified in the suggested procedure, and, as expected, a variety of standards was used. The standards and the mean of the beta results are shown in Table 7.

TABLE 5

Summary of Data, Second Sample

Item	Value
Beta Counting	
Amount of radioactivity in sample, mean value—$\mu c/ml$	6.7×10^{-7}
Amount recovered, mean value—$\mu c/ml$	5.8×10^{-7}
Median $\mu c/ml$	6.3×10^{-7}
Range $\mu c/ml$	(0.2 to 8.2) $\times10^{-7}$
No. of results within ±10% of amount added	22
No. of results within ±50% of amount added	39
Mean deviation from amount added—%	18
Standard deviation from mean—$\mu c/ml$	1.6×10^{-7}
Standard deviation from amount added—$\mu c/ml$	1.8×10^{-7}
Gamma Counting	
No. of results	8
Amount of radioactivity in sample, mean value—$\mu c/ml$	5.2×10^{-7}
Mean of all results—$\mu c/ml$	5.8×10^{-7}
Range—$\mu c/ml$	$1.4-11.0\times10^{-7}$
No. of results within ±10% of amount added	1
No. of results within ±50% of amount added	5

It is apparent that the choice of a calibration standard is an important factor in the accuracy of beta counting. The most popular standard, Tl^{204}, yielded the best results, although insufficient data are available to compare its use with that of Cs^{137} as a standard. The values obtained with C^{14} were surprising, as this low-energy standard is not considered satisfactory for gross beta counting. A variety of other standards was used, including Bi^{210}, Y^{90}, and Ra D&E. The data are insufficient to evaluate these nuclides individually, but the mean of the data from fourteen laboratories is sufficiently low to suggest that they are not satisfactory standards for beta counting.

It was presumed that the best results from this sample would be obtained by using Cs^{137} incorporated into a series of aliquots of varying solids thickness to yield a self-absorption curve. Only two laboratories used this procedure, but each obtained a value of 6.3×10^{-7} μc/ml, which was significantly higher than the data mean obtained by the other participants. Further study is necessary to determine the value of Cs^{137} as a calibration standard.

Sample Thickness

As in the first sample study, the effect of solids was readily apparent.

TABLE 6

Evaluation of Counting Instruments Used

Instrument	Mean Radioactivity $\mu c/ml\times10^{-7}$
End window (9 results)	6.0
Gas flow end window (6 results)	5.9
Geiger-Mueller end window (3 results)	6.2
Internal proportional (34 results)	5.8

TABLE 7

Standards Used and Mean of Beta Activity

Standard	No. of Results	Mean Beta Activity $\mu c/ml\times10^{-7}$
Tl^{204}	17	6.2
Cs^{137}	5	5.8
C^{14}	7	6.0
Other	14	5.2

Table 8 summarizes the solids factor.

The sample volume (500 ml) specified in the suggested procedure would give satisfactory thickness in 2-in. planchets but would be too thick for 1-in. planchets. A 250-ml sample or smaller would have been preferable for those laboratories using the 1-in. diameter planchet. From the sample-thickness results, it is apparent that laboratories using an aliquot of sample yielding less than 20 mg/sq cm obtained better values than those using a thicker absorption layer. It should be noted that of the 22 agencies comprising the ±10 per cent group (Table 5), only 2 reported sample thickness values greater than 20 mg/sq cm.

Gamma Counting

Because of the small number of agencies submitting gamma results, the usual statistical parameters could not be applied. The gamma results shown in Table 5, however, suggest that the precision of gamma counting is less than that of beta counting, and that the mean of the results tends to be higher rather than lower than the actual activity of the sample, as shown by the beta results. Most of the agencies used Cs^{137} as a gamma standard and employed a scintillation spectrometer. Further study is needed on the factors affecting the gamma-counting efficiency.

Conclusions From Second Sample

On the basis of results obtained with the second sample in the radiologic series, these conclusions seem warranted:

1. Equally reliable results can be obtained with either the end-window counter or the internal proportional counter, provided the geometric factors of the end-window counter are carefully considered.

2. The use of Tl^{204} as a beta calibration standard appears to be satisfactory. Cs^{137} is a satisfactory standard also and, when used to develop self-absorption curves, may be superior to Tl^{204}. Although good values were obtained with C^{14}, the disadvantages of low energy and solids absorption make it less desirable as a standard.

3. The best results for gross beta counting were obtained when sample aliquots yielding solids thicknesses of 20 mg/sq cm or less were selected.

Comparison of First and Second Samples

To evaluate the use of the prescribed sample-preparation procedure used in the second study, it is necessary to compare the precision and accuracy of the second study with that of the first, where no specific procedure was suggested. This comparison is shown in Table 9.

From Table 9 it is apparent that there has been improvement in performance. The mean percentage of beta activity recovered increased from 76 per cent to approximately 87 per cent; the percentage of results within ±10 per cent of the true value increased from 31 per cent to 51 per cent. The improvement in performance must be owing in part to the use of a standard sample-preparation procedure. With 21 of the 41 agencies participating in both sample studies, however, the improvement noted may be owing also to attention to the factors discussed in the first-sample report. From the viewpoint of the Analytical Reference Service, it is encouraging to find that participation in the program on the part of the 21 laboratories may have resulted in increased accuracy in gross radioactivity measurements.

TABLE 8

Sample Thickness

Thickness	No. of Results	Mean Beta Activity $\mu c/ml \times 10^{-7}$
< 20 mg/sq cm	31	6.3
> 20 mg/sq cm	7	4.5
Not given	5	5.2

TABLE 9

Comparison of First and Second Samples

Item	First Sample	Second Sample
No. of agencies participating	25	41
Amount of beta activity in sample—$\mu c/ml$	5.44×10^{-7}	6.7×10^{-7}
Mean beta activity recovered—$\mu c/ml$	4.13×10^{-7}	5.8×10^{-7}
Beta activity recovered —%	76.0	86.6
Results within ±10% of amount added—%	31	51
Standard deviation from amount added	2.3	1.8

Significance of Laboratory Determinations

In both of the studies described, the reported radioactivity was below the level actually present in the sample. Only 76 per cent and 87 per cent, respectively, of the true activity were recovered. If the performance of the participating laboratories is typical of the majority of health agencies doing radiologic monitoring, the actual amount of radioactivity present in environmental samples must be higher

than the reported values. The situation emphasizes the need for close attention to all factors affecting the efficiency of gross radioactivity measurements and the need for increased study to develop standard procedures for this important laboratory determination.

Summary and Conclusions

The data obtained by distribution and analysis of two reference samples of water containing a radionuclide provide support for the following general conclusions:

1. Approximately half the agencies participating in the study series were able to determine gross radioactivity within 10–15 per cent of the true activity of the sample.

2. The majority of the reported values were significantly below the true activity of the sample, suggesting that the true radioactivity of environmental samples may be higher than currently reported.

3. In the preparation of water samples for counting, a solids drying temperature of not more than 100°C must be maintained to prevent loss of volatile radionuclides.

4. Of the available standards for instrument calibration, either Tl^{204} or Cs^{137} appears to be satisfactory for beta counting, and Cs^{137} appears to be satisfactory as a gamma standard. The use of other standards tends to affect the reliability of the results adversely.

5. In the counting of water samples for gross beta radioactivity, a solids thickness of 20 mg/sq cm or less is imperative.

6. The internal proportional counter is the instrument of choice for the counting of gross beta activity, although the end-window counter may yield satisfactory results if geometry factors are rigidly controlled.

7. Further research and evaluation are needed to develop adequate standardized procedures for the determination of gross beta and gamma radioactivity of environmental samples.

Experience With Anthracite-Sand Filters

Walter R. Conley

A paper presented on Jun. 5, 1961, at the Annual Conference, Detroit, Mich., by Walter R. Conley, Sr. Engr., General Electric Co., Richland, Wash.

THE General Electric Co. operates eight large filter plants for the Atomic Energy Commission (AEC) at the Hanford, Wash., facility. Because water is important to the process, improved water treatment methods have been developed. The work has resulted in important capital and operating savings and in the production of better quality water.

General Observations

Results of laboratory,[1] pilot plant, and full-scale plant tests with a variety of filter types over a period of 16 years show that filters made of anthracite and sand together are superior to filters made of either material alone.

The plants have used six main filter types. The comparative value of these filters is determined by their ability to produce high-quality water at high filtration rates and with long filter runs. On this basis of judgment, filters made of 6 in. of 0.43-mm effective-size sand and 24 in. of 0.9-mm effective-size anthracite are superior to any of the other filter types used.

Optimum performance with all the filter types tested is obtained when the coagulant feed does not exceed the amount necessary to cause the suspended matter in the raw water to grow large enough for retention by the filters. Excess coagulant feed promotes floc breakthrough. The effect is serious when the water is cold and the filter flow rates are high. The breakthrough is controlled by reducing coagulant feed and adding a few parts per billion of polyacrylamide or polysaccharide to the filter influent.

Very little attention is given to floc size or quality, but the filtrate from each filter is routinely monitored for turbidity. If the turbidity readings obtained are higher than planned, the chemical feeds are changed.

The chemical treatment methods and superior filters have led to better water at low capital and operating costs. At nominal cost, water flow increases have been attained which would have cost over $20,000,000 in capital investment if conventional methods had been used. Operational costs have been reduced significantly. Savings in chemical costs alone have been over $250,000 a year since 1957. Filtered water quality has been so good that special highly sensitive methods had to be developed to measure the turbidity.

The large capital savings were made possible by increasing the flow through all the plant components. Consequently, flocculation and settling times are short and filtration rates are high. For a long time one plant filter operated successfully at 8 gpm/sq ft, with very short flocculation and settling times. Most of the plants are capable of operating at 6–7 gpm/sq ft.

The limitation to still greater flow rates is air binding of the filter media. The air binding causes short runs at high filtration rates during a few weeks each year.

There has been no difficulty in keeping the filters clean. The percentage of backwash water used is usually below 2 per cent of gross output and is often below 1 per cent.

History of Hanford Filters

Filters made of anthracite and sand were used throughout the country for many years before they were used at Hanford. The original Hanford filters consisted of 10 in. of 0.45-mm sand and 20 in. of 0.7-mm anthracite. It took many years of effort to obtain filters that performed better than the original type.

TABLE 1

Media Depth and Performance

Filter Type No.	Sand Depth *in.*	Anthracite Depth *in.*	Rank	
			Good Quality	Low Head Loss
1	30		1	9
2	20	10	2	8
3	15	15	3	7
4	10	20	4	6

Additional filter plants were built during the first Hanford expansion. A plant study was made to see if there would be an advantage in using filters made entirely of sand instead of the sand and anthracite combination. The results of a test on one plant size filter showed that the sand filter gave runs which were only half as long as those given by the combination filters. Additional plant tests were run using various depths of anthracite and sand. The tests showed that water quality was improved by increasing the depth of sand and decreasing the depth of anthracite. Data from these tests were used to design the filters for three new plants. These filters had 20 in. of 0.45-mm sand and 10 in. of 0.7-mm anthracite. The filters were very successful, but no attempt was made to operate them at high filtration rates. Performance characteristics of these filters are shown in Table 1.

The effective size of the sand was 0.45 mm, and the uniformity coefficient was 1.5. The effective size of the anthracite was 0.7 mm, and the uniformity coefficient was 2.0.

At this point, a long-term investigation was begun to evaluate filters and chemical treatment methods with the goal of increasing the water output of the plants. These tests led to the adoption of the alum-activated silica process as used by Baylis [2, 3] at Chicago. The results were successful, although treatment costs were higher than desired, and control of the process was difficult.

The test program also resulted in development of a filter that was capable of higher flow rates than the types then in use. The new filter consisted of 3 in. of 0.45-mm sand and 27 in. of 0.7-mm anthracite. This design was used in the construction of the filters for two new plants. These plants operated very successfully at high rates. Because of the success of the plants, it was decided to convert some of the older filters to the new type. All the anthracite and all but 3 in. of the sand was removed from the old filters, and 27 in. of new anthracite was added, but these filters did not produce good quality water unless additional chemicals were used. The poor performance was found to have been caused by the method of sand removal. The top sand which had been removed contained a rela-

tively large amount of fine material. The remaining sand had an effective size of about 0.59 mm. The performance of these filters was brought up to standard by the addition of sand of the proper size, 0.45 mm. Performance characteristics of two types of filters with different sand size are shown in Table 2.

During 1956 and 1957, a new chemical process was adopted to replace the alum-activated silica process. The new process consists of coagulation with alum followed by addition of a few parts per billion of a polyacrylamide as the water enters the filters. At about the same time, a number of the filters were changed to give a medium consisting of 6 in. of 0.43-mm sand and 24 in. of 0.9-mm anthracite. The anthracite size in the filters was changed by adding coarse material and skimming off the fine materials from the surface of the filter beds. The results have been excellent. The converted filters have a practical capability of 6–8 gpm/sq ft, depending on the flocculation and settling time and the size of the filter effluent piping.

One filter was made of 1.3-mm anthracite and 0.43-mm sand. This filter was not as good as expected, either in head loss or water quality. The sand and anthracite mixed together to such an extent that there was no distinct sand layer. In spite of the rather complete mixing, this filter ranked first in head loss and was acceptable in water quality. Performance data for filters made of different sizes of anthracite are shown in Table 3. Depth of sand was 6 in., and depth of anthracite was 24 in.

It will be noted from the tables that none of the filters are ideal. An ideal filter would rank first in both water quality and head loss. In the tables, the filter that produced the best water had the worst head loss characteristics. The filter with the least head loss produced next to the worst water quality. Nevertheless, the difference in water quality produced by all the filters shown in the tables, except the one with 0.59-mm sand, is so small that it is undetectable by the usual analytical methods. The light-scattering microphotometer method used at Hanford is sensitive enough to show a difference in water quality among the other filters. All the filters produced water containing less than 0.01 ppm turbidity on the Hanford scale, which is relative.[4] An arbitrary calibration method was adopted in order to get the instruments into early use in the plants. The technical problems associated with absolute calibration still have not been solved, but the absolute turbidity values are thought to be considerably higher than the reported relative values. The arbitrary calibration has been so useful, and the plant operators have become so accustomed to the scale, that it has not been changed since the initial calibration. Few instruments * can detect a value of 0.01 ppm on the Hanford scale. This value cannot be detected by the naked eye looking at a submerged clearwell light.

TABLE 2

Sand Size and Performance

Filter Type No.	Sand Effective Size *mm*	Rank	
		Good Quality	Low Head Loss
5	0.45	5	4
6	0.59	7	3

* A low-range turbidity meter manufactured by the HACH Company, Ames, Iowa, has the same order of sensitivity as the Hanford instrument. Other instruments may also have the required sensitivity.

It will be noted from the tables that anthracite depth and size have a major effect on filter head loss. The length of filter run from the worst to best filter differs by a factor of over 3. The filter performance index of the best filter is in the range of 600–2,200 gal/sq ft/ft of head loss.

Alum Feed and Filter Performance

A coarse-grained filter medium with a relatively high alum feed will produce a filtrate as clear as that produced by a fine-grained medium at a relatively low alum feed until the filter breaks through. Unfortunately, high alum feed contributes to early filter breakthrough. The practical effect is that relatively high alum feeds cannot be tolerated if long filter runs and high filter rates are necessary. A filter must be selected that will make it possible to get good water at relatively low alum feed rates.

TABLE 3

Anthracite Size and Performance

Filter Type No.	Anthracite		Rank	
	Effective Size mm	Uniformity Coefficient	Good Quality	Low Head Loss
7	0.7	2.0	4	5
8	0.9	1.5	4	2
9	1.3	1.8	6	1

Effect of Filter Conditioners

Breakthrough can be controlled if enough polyacrylamide, another filter conditioner, or activated silica is fed. These materials control breakthrough but increase filter head loss. For this reason, a filter must be selected which will not require an excessive amount of these chemicals to control breakthrough.

In addition to controlling breakthrough, polyacrylamides or polysaccharides fed to the water as it enters the filter cause a general decrease in filtrate turbidity when flow rates and alum feeds are high. The polyacrylamides and polysaccharides cause an improvement in water quality and an increase in head loss that would not be considered normal for the filter media size used.

Operational Control

Properly made anthracite-sand filters provide a means for increasing water plant capacity without making any other basic plant changes. These filters cannot accomplish their purpose unless alum feed and polyacrylamide feed are controlled accurately and correctly.

Primary emphasis is placed on systematic sampling of all filters and of the general plant effluents for turbidity with a light-scattering microphotometer.[5] The analytic information is used to regulate the chemical feeds. Procedures have been worked out that allow the operators to produce filtered water to any reasonable specification with remarkable consistency.

Floc tests are no longer run for operational control because turbidity measurement of the filter effluent gives more reliable results.

Air Binding

Columbia River water is saturated with air. This air causes short filter runs during a 4–8-week period every year. Enough air accumulates in the filter media to reduce runs to about one half of normal. The effect of the air can be reduced by removing from the filters all anthracite that passes a 20-mesh sieve. The air binding can be reduced by increasing the depth of water standing over the anthracite.

Anthracite Loss

Anthracite loss during backwash has been 1–4 in./year depending on the frequency of backwash. Most of the anthracite is lost during the period when air binding is a problem. It is thought that the air floats the anthracite out of the filters during backwash. The loss is not a serious problem either in terms of money or of operating efficiency. The lost material is replaced every year or two. The annual cost of the anthracite is less than 10 per cent of the annual cost of alum.

Sand Loss

Some sand is lost through the underdrain system for some filters. The underdrain system consists of gravel and a Wheeler bottom. On some of the older filters, sand loss has increased to the extent that replacement of the gravel is being considered. Lost sand has been replaced at an annual cost of less than 1 per cent of the annual cost of alum.

Mud Balls

The filters are equipped with rotary surface wash devices. These devices have been so successful that mud balls have not been found after 16 years of operation.

Relative Importance of Process Steps

Based on numerous laboratory, pilot plant, and full-scale plant tests, as well as on general operating experience, the process steps in water filtration of Columbia River water are listed in the order of their importance: (1) Alum feed control, (2) Polyacrylamide feed control, (3) Filtration, (4) Flocculation, and (5) Settling.

If the first three process steps are adequate, the last two are of minor importance. For this reason, more attention is given to these steps, both in plant design and in operation.

On a pilot plant scale it has been shown that when the first three steps are adequate, the last two steps can be eliminated without any effect except short filter runs. Hanford plant experience has confirmed the pilot plant work in the range of 30–120 min flocculation and settling time.

General Conclusions

Filters made of the proper sizes and depths of anthracite and sand together are superior to filters made of either material alone. The effect of chemical treatment on water quality and head loss is greater than that of filter media composition or any other plant variable.

Limitation of Observations

The observations made in this paper apply with certainty only to Columbia River water at Hanford. This raw water contains an average of about 100 ppm total dissolved solids. The organic content is relatively low. Turbidity of the raw water is usually low except during the spring. Extreme values of 1 ppm and 1,600 ppm have been observed. Water temperatures are relatively cold, being below 10°C for several months every year.

Flocculation and settling are considered essential for practical operation when river turbidity is high. Although water quality can be maintained without conventional flocculation and settling when river turbidity is high, filter runs will be too short for practical operation. Optimum flocculation, settling times, and filtration rates will vary widely, depending on the nature of the raw water. Test data should be obtained before optimization is attempted.

Although the Hanford turbidity data have always been referred to as rela-

tive, some people have assumed that the numbers were at least fairly close to the turbidity values in *Standard Methods*.[6] This is not true. Recent measurements, starting with a 100-ppm fullers earth standard as checked by a turbidimeter, indicate that the Hanford relative measurements should be multiplied by about 50 to give a *Standard Methods* turbidity. Much work needs to be done on this subject, however, before a final conclusion is reached. The range of interest at Hanford is between 0.001 and 0.01 ppm on the Hanford scale, which is the range of distilled water. As most other turbidity measurements assume that distilled water is turbidity free, they are also in error. It is believed that the *Standard Methods* turbidity of the best obtainable water is about 0.05 ppm and that single-distilled water is rarely better than 0.25 ppm, and is often 0.5 ppm turbidity.

Personnel

The good results obtained with the Hanford filter plants reflect the work of many people. Research and development work on this problem has been more or less continuous since 1943. At times, as many as five engineers and chemists have worked essentially full time on this problem. Over twenty engineers and chemists have made important contributions. Particularly noteworthy was the work of R. W. Pitman, who made important contributions in developing adequate control methods, and who first discovered the action of polyacrylamides on filter performance.

The work of the operating personnel is equally noteworthy. The skill and effort of over 100 supervisors and operators made it possible to apply quickly the information developed by testing. Many problems not discovered by testing appeared to threaten the success of operations, but they were solved by the operating personnel. The overall success of the Hanford filter plants is witness to the good management, high morale, and skill of the operating personnel.

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Discussion

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The water supply industry is indebted to Conley and his associates at Hanford for their development of the light-scattering microphotometer as a means of measuring very low turbidities for the operational control of water filtration plants at relatively high filter rates. Experience during 16 years at the Hanford works with laboratory, pilot plant, and full-scale tests in the operation of large filter plants has shown conclusively that the use

of anthracite and sand together permits very much higher filter rates than with either material alone. Most of the plants at Hanford are capable of operating at 6–7 gpm/sq ft. One plant has operated successfully at 8 gpm/sq ft with turbidities not in excess of 0.05 ppm in the filter effluent.

The writer fully agrees with Conley that the best and most economical way to increase the capacity of an existing rapid sand filter plant is to increase the rate of operation rather than to build additional units. It is most reassuring that filter rates as high as 8 gpm/sq ft can be used with proper filter media and proper control of the chemical dose from the turbidity of the effluent of each filter. Conley's experiments indicate, however, that a filter aid or filter-conditioning chemical must be used in addition to the alum for the filter to operate at the higher rates without breakthrough, and that the filter-conditioning chemical is best applied in the filter influent right after sedimentation.

Bacterial Removal

Undoubtedly the removal of suspended matter from the water, as indicated by turbidity removal, is a prime objective at the Hanford works of AEC because of the absorption of radiation by suspended matter. Conley and his associate, Raymond W. Pitman, have implied in previous papers [1, 2] that bacterial removal by the filters should be as good as turbidity removal because "many of the turbidity particles in raw water are smaller than bacteria." The writer doubts that any particles smaller than bacteria contribute to turbidity, because freely dispersed bacteria are colloidal in size (1 μ or less). Colloidally dispersed solids may produce color, but probably not turbidity. Conley reports turbidities of the Columbia River raw water as being in the range of 1–1,600 ppm. For a limit of 0.05 ppm in the filter effluent, the required turbidity removal throughout the plant is in the range of 95–99.997 per cent. Bacterial removals of 99.997 per cent can readily be obtained with rapid sand filters and heavy chlorine doses, but the removal to be expected in the filter itself does not exceed about 99 per cent. The dilution equivalent of a bacterial removal of 99.997 per cent is about 33,000:1, whereas the dilution equivalent of a bacterial removal of 99 per cent is only 100:1. Thus heavy chlorination is more than 100 times as effective as filtration alone.

Mixing of Media

The writer has been designing anthracite-sand filters for nearly 20 years. The first installations were in pressure filters for swimming pools, but in recent years all municipal filtration plants designed by the writer's firm have employed anthracite on top of silica sand. The coarse-grained anthracite medium has been employed to allow deep penetration of floc and correspondingly long filter runs. The finer-grained sand beneath the anthracite is relied on as a polishing agent to remove most of the floc remaining after passage of the water through the coal. In order to take full advantage of the effectiveness of the finer sand grains just below the coal, the firm has designed its filters to avoid or to minimize mixing sand and coal during backwashing. Relatively deep sand beds have been used for avoidance of filter breakthrough, which was reported in so many of Conley's experiments.

Anthracite, with a specific gravity of 1.4–1.6 and greater angularity than silica sand, must have a grain size of

2–3 times that of the sand with a specific gravity of 2.65 to be lifted at the same wash rate. If the size ratio at the interface between the sand and the coal is greater than about 3, there will be mixing at the interface during washing. The larger the size ratio, the greater will be the mixing of the two media. Table 4 shows comparable data on filter media from some of the filters at Hanford [3] and some of the filters designed by the writer's firm. It will be noted that the interface size ratios for all filters designed by the firm are in the range 2.8–4.0. Washing experiments in 2.5-in. glass tubes for most of these filter media show no substantial mixing at the interface. The materials in filters 2–5 mix over a depth of about 5 in.

The interface size ratios of the Hanford filters as shown in Table 4 are in the range of 4.8–8. Conley reports [2] substantial mixing at the interface with all these filters and claims "a very favorable influence on head loss because the finer sand grains cannot form an impervious mat when mixed with coarse anthracite." Figure 1 shows the head loss distribution for the Hanford test filters at the end of runs.

Test Filter A, with 24 in. of anthracite on top of 6 in. of sand, had a small grain size at the top of the anthracite, which resulted in rapid clogging and high rate of increase of head loss. The top coal size, 0.42 mm, was the same as the top sand size. Most of the floc that penetrated the coarser coal was subsequently removed by the fine sand at the top of the 6-in. sand layer, resulting in rapid clogging and high head loss in this layer. If there had been no mixing at the interface, the curve for Filter A in Fig. 1 would be as shown by the broken line at the top of the sand layer. Similar mixing is shown to a much greater extent by the broken line for Filter B. The mixing for Filter C was even greater. Conley and Pitman reported that sand particles were observed as high as 12 in. up into the anthracite on Filter C.

The principal difference between the writer's use of anthracite-sand filters and the practice at Hanford is that the writer's firm designs the filters for a minimum of mixing at the interface, and the Hanford filters are de-

TABLE 4

Comparative Data on Filter Media

Source of Data	Anthracite			Sand			Interface Size Ratio
	Depth in.	Top Size mm	Bottom Size mm	Depth in.	Top Size mm	Bottom Size mm	
Hanford:							
Test Filter A	24	0.42	2.0	6	0.42	0.59	4.8
Test Filter B	24	0.84	2.0	6	0.42	0.59	4.8
Test Filter C	22	1.00	3.36	8	0.42	0.59	8.0
Recommended	24	0.84	2.0	6	0.42	0.59	4.8
Massachusetts:							
Billerica, Mass.	18	1.19	1.68	30	0.59	1.19	2.8
Cambridge, Mass.							
Filter 1	10	0.59	1.68	20	0.59	1.19	2.8
Filters 2–5	13	0.59	1.68	16	0.42	1.00	4.0

The principal difference between the writer's use of anthracite-sand filters and the practice at Hanford is that the writer's firm designs the filters for a minimum of mixing at the interface, and the Hanford filters are de-

signed with a high degree of mixing. It is the writer's belief that the sand will effect a higher degree of suspended-solids removal if the top sand is not mixed with the coarser coal grains at the bottom of the coal. The writer's firm has made no turbidity measurements to determine if this is so. The writer suspects that the excellent removal of turbidity obtained at Hanford results primarily from the use of filter-conditioning chemicals and close chemical control, and is obtained in spite of the mixing of sand and coal at the interface.

Experience in Massachusetts

At the Billerica, Mass., filter plant, 18 in. of relatively coarse anthracite is placed on top of 30 in. of relatively coarse sand, as shown in Table 4. The

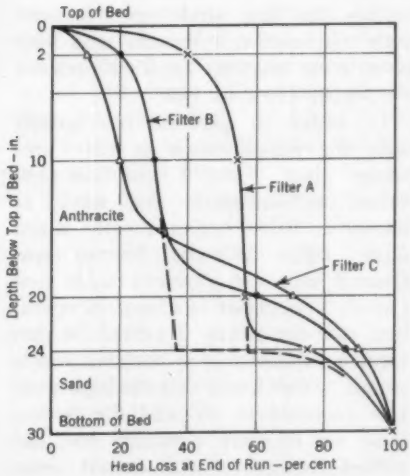

Fig. 1. Head Loss Distribution for Hanford Test Filters

Curves for Filters A and B would have followed the broken lines if there had been no intermixing at the sand-anthracite interface.

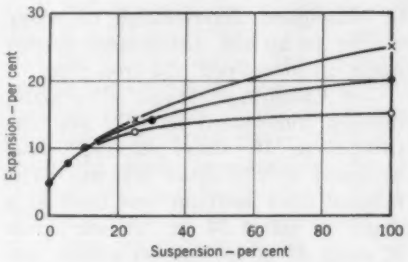

Fig. 2. Suspension as a Function of Expansion During Washing for Cambridge Filter 1

Top curve represents 10 in. of 14-30 US sieve anthracite. Middle curve represents 20 in. of 16-30 US sieve sand. Bottom curve represents 20 in. of 16-30 US sieve sand under 10 in. of anthracite.

sand is supported on porous plate filter bottoms with no gravel. This plant has been in use for about 6 years, treating a river water of extremely variable quality. The turbidity is relatively low, but the water frequently contains high color, iron and manganese, and algae and coliform counts up to 200,000 per 100 ml. Pretreatment consists of very high chlorine doses, coagulation with alum, use of activated carbon, and settling. The filter plant effluent has been uniformly good in quality, even though algae counts in the raw water have occasionally been extremely high. This plant was designed for a filter rate of about 3.6 gpm/sq ft, but such a rate has not been used so far. Residual aluminum in the plant effluent averages less than 0.20 ppm. The iron in the plant effluent averages less than 0.08 ppm, and the manganese averages less than 0.05 ppm. The plant effluent tests have shown no positive portions for coliform to date. The high degree of removal practiced at the Hanford works has no practical value at Billerica because

of subsequent deterioration of water quality in an old distribution system made up of unlined cast iron pipe.

The Cambridge, Mass., filter plant, initially constructed in 1922 and expanded to 16 filters in 1932, was equipped with Wheeler bottoms. The original filter medium was sand to a depth of about 24 in. A wash rate of about 28–30 in. rise per minute was built into this filter plant. Over the years, the top gravel has been displaced from position during backwashing so that the sand has penetrated into the gravel and into the underdrainage system. The nominal design rate for these filters was 2 gpm/sq ft, but it has now become necessary to increase this rate to 3 gpm/sq ft. The filter runs are too short even at the 2-gpm rate. It is thus necessary to replace the fine sand formerly used with combination anthracite-sand beds in order to lengthen the filter runs for the higher filtration rate.

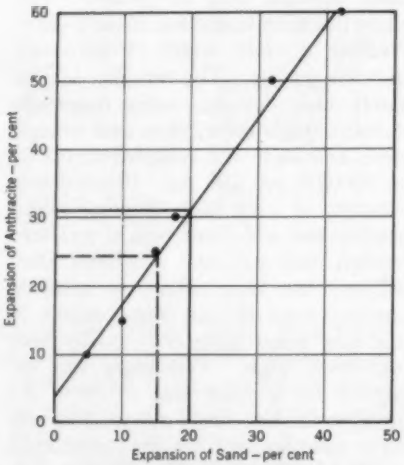

Fig. 3. Relationship Between Anthracite Expansion and Sand Expansion for Cambridge Filter 1

Relationship (diagonal line) was drawn from actual determinations represented by dots. At the broken line, sand was completely suspended. At the continuous vertical and horizontal line, adequate cleansing is assured.

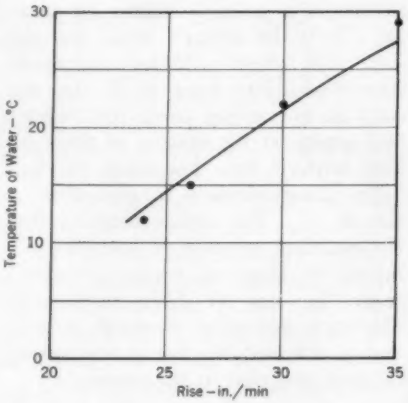

Fig. 4. Wash Rate for 20 per cent Sand Expansion for Cambridge Filter 1

Curve represents viscosity ratios. Dots represent experimental determinations by backwashing.

In order to proceed intelligently with the rehabilitation of the Cambridge plant, Filter 1 was first converted to anthracite and sand, as shown in Table 1, and used as a test filter. The Wheeler bottom was cleaned out and repaired with new gravel. The filter has been in operation now for nearly 2 years. It performed satisfactorily at first, but within a year, it was found that the high wash rate required to suspend the bottom sand for effective cleansing had disturbed the gravel and caused intermixing of the sand and gravel. It was therefore decided to equip all the filters with porous plate bottoms and remove all the gravel. Filters 2–5 are now being rehabilitated with media as shown in Table 4.

Design Determination by Media

It has long been the firm's practice to design filters around the filter media to be used. Backwash tests are made of the filter media in 2.5-in. glass tubes to determine the percentage of the grains in suspension for various expansions of the beds and the wash rates required for this expansion. For maximum effectiveness of the wash, each grain must be suspended so that the liquid shearing force on the grain is equal to the weight of the grain in the liquid. No greater cleansing force is possible. Figure 2 shows the results of tests to determine the suspension of the media as a function of bed expansion for Cambridge Filter 1. It will be noted from Fig. 2 that the bed must be expanded more than 5 per cent for any of the grains to be in suspension. Figure 2 indicates that suspending all the sand grains with no anthracite on top requires a 20 per cent expansion of the bed. With the coal on top, complete suspension is obtained with about 15 per cent expansion of the sand bed. The coal is 100 per cent suspended when the coal bed is expanded 25 per cent.

Figure 3 shows the relationship between the coal expansion and the sand expansion of Cambridge Filter No. 1. It was determined in Fig. 2 that all the sand would be in suspension when expanded 15 per cent, with the coal above. Figure 3 indicates that under these conditions the coal will be 25 per cent expanded. To provide a safety factor to be sure that all the sand grains are suspended, a 20 per cent sand expansion was adopted for operating purposes. The corresponding coal expansion is 31 per cent.

It will be noted that all the data in Fig. 2 and 3 are functions of the material used in the beds. The relations will be the same regardless of the fluid used for washing. With these data established, it is necessary to determine the wash rate required for a 20-per cent expansion of the sand. The test data for various water temperatures are shown in Fig. 4. The curve shows the viscosity ratios for the various water temperatures fitted to the experimental points. The close fit indicates that the Kozeny equation for streamlined flow of water through granular media may be used without appreciable error, not only for filtration at the high rates so far used, but also for the backwashing process. Figure 4 indicates that when the temperature of the water is about 10°C, a wash rate of about 23 in. rise per minute is required for 20-per cent sand expansion. When the temperature of the water is 30°C, a wash rate of about 36 in. rise per minute is required for a 20-per cent sand expansion. Because the freeboard in the Cambridge filters to the underside of the wash water gutters is very limited, it is essential to change the rate of wash as the water temperature changes. This avoids loss of anthracite during washing in cold weather and suspends all the sand during warm weather.

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Water Supply Problem of Lock Haven, Pa.

Hugh B. Montgomery

A contribution to the Journal by Hugh B. Montgomey, Chief, Div. of Minerals, State Dept. of Forests & Waters, Harrisburg, Pa.

THE Lock Haven Suburban Water Co., located in Woodward Township, Clinton County, Pa. (Fig 1), is a privately owned utility that supplies water for industrial and private consumers within a radius of 6 mi from the source of supply. The consumers are located primarily along Highways 664 and 120, the West Branch of the Susquehanna River, and Bald Eagle Creek, with the largest population at Lock Haven.

The source of supply is Queens Run and its tributary drainage shed, which is located 4 mi north of Lock Haven to the east of the West Branch of the Susquehanna River, and which covers 14 sq mi of drainage shed (Fig. 2). This surface supply is supplemented during periods of peak demand in dry seasons by two rotary-drilled wells, Wells 1 and 2 in Table 1.

The collection and distribution system is composed of a 1-mil gal reservoir on Queens Run Middle Branch, which is drained by one 8-in. line into which a chlorinator injects the chlorine necessary to disinfect the total supply. The 8-in. line delivers the superchlorinated water to the confluence of Queens Run Middle Branch and Queens Run East Branch in Ramm's Hollow, where it is emptied into a 16-in. line which is the principal transporting line. At the confluence of these two pipes is a 12-in. pipe that delivers water from a 3-mil gal reservoir located upstream in Ramms Hollow. A small catch basin lies on an unnamed run near the East bank of Ramms Hollow Reservoir and supplies small amounts of water to the system. The smaller reservoir on Queens Run Middle Branch is also supplied by Well 1; the larger reservoir in Ramms Hollow is supplemented by Well 2.

Supplementary Wells

The demand on the company's water supply nearly exceeds its available supply during extended dry periods. Because it is not currently feasible to utilize additional drainage areas in the immediate vicinity of the existing collection, transportation, and distribution system, it is necessary to supplement surface supplies by tapping the ground water resources. Two wells were drilled to do this. No trouble was met until the water in the largest-producing well became contaminated. Then two additional wells were drilled, but they failed to deliver water when one of the two previous wells was pumping at a high rate. The problem then was to find suitable locations for additional wells that could be successfully drilled to produce acceptable water without being affected by the production of other wells.

Source of Information

The Division of Minerals began to collect information from all known sources. The company provided analyses of water, records of wells, and copies of chemical studies conducted by consultants. Information was provided on the geology of the coal-bearing strata and locations of mine operations. The open-file geologic maps of the Lock Haven quadrangle and a Pennsylvania Geological Survey bulletin [1] were consulted. Field work by the Division of Minerals, coupled with examination of aerial photographs, rounded out the investigation of available information on the area.

General Geology

The area is located approximately 4 mi north of Lock Haven. It is located on the edge of the Allegheny Plateau of the Allegheny Plateau Physiographic Province, and is bounded directly on the southeast by the Ridge and Valley Physiographic Province.

The Ridge and Valley Province is a structurally high area of elongate linear plunging folds that trend northeast-southwest. At the juncture of the two provinces, the strata dip beneath the plateau and are overlain by strata that are not as strongly deformed. The dip of the strata is steep at the edge of the plateau, decreasing in the northwest of the Ridge and Valley Province and in its overlying strata. Faults are present throughout the area, being less obvious on the plateau. Two faults cross the vicinity of the land under discussion, but data on the amount of displacement were not obtainable.

The exposed rocks present in the Lock Haven vicinity range from Ordovician to Devonian in age in the ridge and valley area, and from Devonian to Pennsylvanian in the plateau area. The difference in ages of the exposed strata is due to the intense amplitude of folding in the ridge and valley area, which permitted the erosional activity to penetrate the more resistant strata—Silurian and younger—and then penetrate the softer shale and limestone measures of the older Ordovician, and in some areas the very old Cambrian.

The lithology of the ridge and valley rocks includes marine limestones, dolomites, siltstones, and sandstones. The local limestones are of high quality and are quarried commercially.

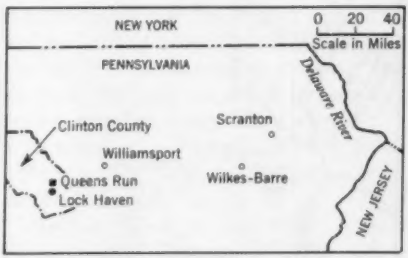

Fig. 1. Location of Queens Run Area in Pennsylvania

The Queens Run water supply provides water for Lock Haven and nearby consumers.

The plateau is underlain largely by rocks of marine brackish and continental lithologies, represented by siltstones, sandstones, redbeds, and fresh and marine limestones. Coal-bearing groups are present, and clay and coal have been mined from them. The mines in the vicinity are shown in Fig. 3.

Ground Water

Ground water is present in the general area and production from the Pottsville formation has been reported.[2]

The interval from the Pottsville formation to the Catskill formation includes the best potential aquifers. This interval is in an economic drilling depth. Wells drilled into the Catskill strata have produced insufficient water to be of interest to the company. One well in the redbeds is reported to have penetrated to a depth of 500 ft and produced only 8 gpm.

Fig. 2. Queens Run and Lock Haven

The surface water supply for the area is supplemented by wells.

From an inspection of Fig. 3, it will become evident that the property in question is underlain by a downwarping of the strata known as a syncline. Because the downward warping is less acute in the northeast than it is in the southwest, the syncline is said to be a southwest-plunging syncline. Furthermore, as the downwarping is elongate and is aligned in a northeast-southwest direction, it can be fully described as a northeast-southwest trending syncline plunging to the southwest. Ground water flowing through such a structure will tend to flow to the center line of the fold and towards the direction of plunge—in this case, the southwest. Such a flow pattern is shown by the arrows in Fig. 3.

It will be further evident from Fig. 3 that the topography causes the drainage of the area to proceed in a direction similar to that of the flow pattern caused by the structural fold. Because the ground water table tends to have a form roughly parallel to the topographic surface, but much more gentle in relief, gravity will cause the ground water to flow downhill beneath the surface towards the center of the property and westward toward the West Branch of the Susquehanna River.

An examination of the outcropping of rocks lying above the redbeds through which the existing wells have been drilled indicates that the strata include formations that appear to be capable of collecting and storing water. Therefore, the arrows in Fig. 3 will illustrate the course of water that has fallen on the surface where some of it has passed over the outcropping rocks and some of it has penetrated the rock. After penetration of the strata, the water has followed the dip of the strata towards the open end of the fold in the direction of plunge and eventually escaped into the Susquehanna River. The primary avenues of flow extend down through the Oswayo sandstone. Immediately below lies the Catskill redbeds, which carry very little ground water.

Well-Drilling and Production History

The first well drilled in this vicinity for the company was in Ramms Hollow. It is designated as Well 2 in Fig. 3. It was drilled in 1941 and was not pumped, after having been tested and rated at 900 gpm. During 1942–1955, a drought necessitated its use as a supplemental supply; it was pumped around the clock in spurts of two weeks or more through the dry seasons. The well was not needed in 1956. The year 1957 was very dry, so the well was used extensively then. In October 1957, Well 2 began to produce acid water. The company was ordered to cease pumping the well because of complaints about fish kill and the high iron content, but later the company was allowed to resume operations. Complaints continued against the staining caused by the high iron content of the water. The aid of a consulting firm was enlisted, and the firm suggested aeration, limestone neutralizing aids, and sealing off the source of contaminated water in the well. A driller was employed, a packer was set at 150 ft, and the acid water was shut off, but iron content remained objectionably high.

The second well drilled was that shown as Well 1 in Fig. 3 and located near Queens Run Middle Branch. It was completed in 1952 with a rating of 400 gpm. It was pumped seasonally during droughts until 1957, and never failed until 1957, although it was never necessary to pump to its limit. In October 1957 it went dry at the same time that Well 2 began to deliver acid water. The original 300-ft depth of Well 1 was extended to 400 ft. Additional water was obtained from it to increase its rating to 450 gpm.

With the development of acid conditions in Well 2 and the temporary failure of Well 1, it was decided in 1958 to drill a third well in Ramms Hollow to provide good-quality water and assure deliverability. Site 3 as shown in Fig. 3 was chosen, and a 600-ft well was drilled. Water flowing at a rate of 80 gpm was encountered. The well penetrated the Catskill redbeds, but there was no increased flow of water from the portion penetrated.

The company wanted a large flow of water, so it decided to drill Well 4 150 ft downstream from Well 3. It was completed to the top of the Catskill redbeds at a depth of 300 ft, where the driller recommended stopping because of the poor chance of large water water supplies from the redbeds. It was rated at a capacity of 175 gpm. While testing Well 4, the water level of Well 3 sank to 100 ft.

Neither Well 3 nor Well 4 was pumped until September 1959, when Well 4 was pumped and became dry after 10 min of pumping. Well 2, which was 2,000 ft away, had been pumping continuously since Aug. 6, 1959.

Geologic Explanation of Well Performance

On examination of the diagrams, it will be noted that a clay mine is present about 1,000 ft west of Well 1 and that a coal mine is present 2,500 ft west of Well 2. The mines are up the slope of the structural strata dip from the well locations. They are located on the top of the hill and, therefore, their surface and ground water drainage will tend to flow, in part, southeast from the high point of the

TABLE 1

Existing and Proposed Wells

Well	Year Drilled	Depth *ft*	Geologic Formation at Bottom of Hole	Capacity *gpm*	Geologic Evaluation	Topographic Evaluation	Surface Exposure Evaluation	Engineering Evaluation
1	1952	300	Oswayo	400	*very good:* near bottom of syncline	*fair:* near headwaters of topographic drainage basin	*fair:* drainage from old clay mine	*good:* above reservoir, shallow hole to red rock
1	1957	deepened to 400	Oswayo	450				
2	1941	375	Oswayo	900	same as Well 1	same as Well 1	*poor:* drainage from old coal mine	same as Well 1
3	1958	600	Oswayo; hole penetrates red beds	80	*fair:* higher in syncline; less drainage area	same as Well 1	*very good:* no surface excavations to interfere	same as Well 1
4	1958	300	Oswayo	175	same as Well 3	same as Well 1	same as Well 3	same as Well 1
5*	1959	342		175	*good to fair:* well down flank of syncline but near projection of fault intersecting coal mine	*good:* In middle of drainage basin	*very good:* no road cuts, mines or other excavations	*good:* Least pressure to pump against. Close to reservoir. Well 2 3,000 ft away
6*					*good:* well down flank of syncline	same as Well 5	same as Well 5	*good:* moderate pressure to pump against
7*					*good:* deep in syncline	*very good:* near discharge point of drainage basin	*fair:* road cut and nearby stream	*good:* greatest presure to pump against
8*					*very good:* near bottom of syncline	same as Well 7	*very good:* no road cuts.	*fair:* line already used to capacity
9*					same as Well 8	same as Well 7	*good:* no road cuts, near clay mine, but probably not too near	same as Well 8

* Recommended sites.

topography and ground water table toward Well 1 and 2.

The ability of the water to travel from the mine to the zone drained is explained in part by the natural structural and ground water flow gradient toward the well from the mine, and by the probable existence of porous and permeable strata and fractures in the rock, as detected at the outcroppings in the area, which could be serving as channelways from mine to well. In general, the joints in a fold trend parallel and perpendicular to the dip direction of the folded strata. The joints perpendicular to the fold thus serve as effective avenues for migration down the dip, in this case from the mine to the well. In highly jointed rock, ground water can move through it with little or no filtration, as the joints act as 90 per cent or more of the total effective permeability.

The composition of the water is typical of water being discharged from coal mines; this further suggests a connection between water escaping from the mine and water pumped from the well. Corroborating evidence is found in the deposits of yellow-to-red basic ferric sulfates and ferric hydroxide beginning immediately below the discharge point of the well and in the positive acid ratings that were detected.

With these observations it is possible to proceed to an explanation of individual well performances.

Performance of Well 1

Well 1, drilled in 1952, initially produced a satisfactory amount of water, although it had a slight excess of iron. The well went dry in 1957, was deepened 100 ft, and has pumped water of equal quality since then.

The well went dry because the water table had sunk and the well no longer penetrated the saturated zone. The table sank perhaps because of extensive drain on the reservoir by Well 2 in 1952–57, and because of a dry seasonal cycle. The deepening of the well to the lower zone of saturation could account for the increase in flow.

Performance of Well 2

Well 2, drilled in 1941, delivered 400 gpm or more of water in 2-week spurts from 1942 to 1957, except in 1956, when it was not used. No information is available about the character of the water, but the existence of yellow iron deposits in the stream beds suggest it had delivered iron-rich waters over the entire period. In 1957, the water began to discharge great amounts of iron flocculents and acid water. A packer was set at 150 ft below the surface, and pumping continued. There was a slight improvement in the water.

The high potential flow rate of 900 gpm and the high iron content of the water strongly suggest that the mine at the top of the hill, up dip from the well, is serving as a source for water production from Well 2. Coal seams and the associated waste bands are commonly high in iron-bearing minerals that readily produce water-soluble, iron-bearing compounds which later take part in chemical reactions causing the precipitation of yellow-to-red iron-bearing deposits.

These iron-bearing materials were tolerable from 1942 to 1957 because the water pumped in 2-week spurts was probably a small percentage of the total supply. Therefore, the water was diluted to tolerable iron-bearing limits. Since 1957, with the greater pumping

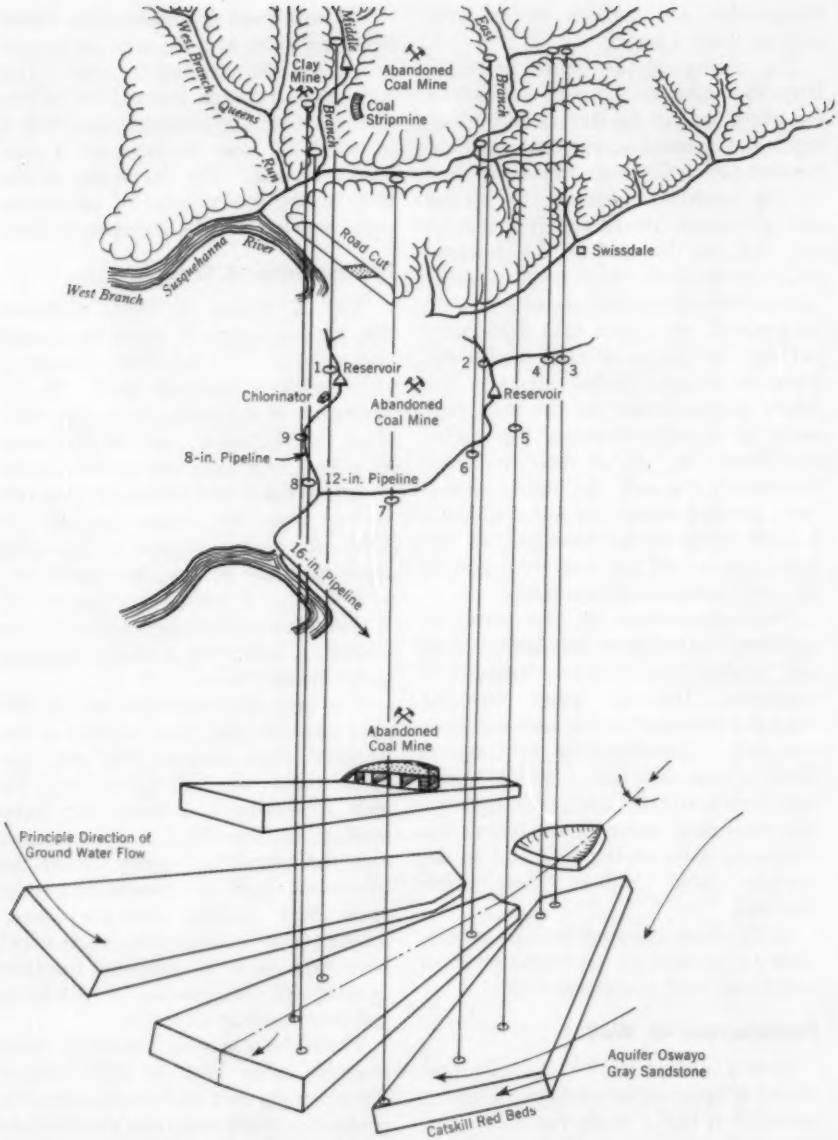

Fig. 3. Topography, Pipelines, Wells, and Subsurface Geology

Ground water in the aquifer flows in approximately the same direction as surface water in Queens Run.

of Well 2 and a greater percentage of the total supply represented by ground water, dilution by surface water did not reduce the iron content to a tolerable limit.

Well 2 never went dry, even though it was pumped heavily in 1957, because it was structurally low in the downfold of the strata and penetrated deeply into the water table or saturated zone. As Well 2 is more than a mile away from Well 1, it is doubtful that its pumping had much influence on the failure of Well 1.

Performance of Well 3 and 4

The serious condition encountered in 1957 of well failure and acid waters encouraged the drilling of Well 3 and 4 in 1958. Well 3 was rated at about 80 gpm. The flow was too small for the company's needs, so Well 4 was drilled 150 ft downstream from Well 3. In 1959, a 24-hr test on Well 4 drew Well 3 down 100 ft, and both wells were pumped dry in a few minutes. Well 2 had been pumped for a month before this test. The quality of the water from Well 3 and 4 was good, because the wells were delivering water that was not supplemented by mine drainage.

The 24-hr pumping test on Well 4 definitely indicated that a 150-ft spacing is too close and that the cone of depression resulting from the pumping of Well 4 was affecting the reservoir area in which Well 3 was located. It also appears that the cone of depression of Well 2 had spanned the 2,000-ft interval between it and Well 3 and 4. Well 2 had effectively drained that part of the reservoir. The short time taken to pump Well 3 and 4 dry is an indication that this is a reasonable assumption.

Recommended Location of Wells

Based on the foregoing analysis, it was recommended that wells should be located, where possible, in the lowest part of the synclinal structure, because the structure tends to divert water toward the center of the downfold and toward the river. The topography tends to gather the water from a broad area and divert this surface drainage to a point of discharge into the river. In general, when porosity and permeability permit penetration, the place where the greatest amount of surface water is present for the greatest length of time will be the site of greatest recharge of the subsurface. Thus wells should be located toward the mouth of Queens Run to take the greatest advantage of the surface drainage of the area and its effect on recharging subsurface aquifers.

Locations on the west bank of the Middle Branch and the east bank of the East Branch of Queens Run and locations near a suspected fault transecting the coal mine above Well 2 should be avoided to minimize the danger of completing a well that will drain waters from the mines.

Table 1 provides an analysis of sites 5–9, which have been suggested as sites for future drilling.

Spacing of Wells

It was further recommended that wells should be at least 2,000 ft apart, as indicated by the apparent effect of Well 4 on Well 3, 150 ft away, and of Well 2 on Well 3 and 4, about 2,000 ft away.

Acid Water

It was suggested that perhaps lowering the packer in Well 2 might correct

the acid water if the influx of acid water is caused by failure of the packer, tubing, or wall of the hole. Abandonment of Well 2 and the drilling of new wells where acid water from mines would not affect them was considered to be the best course of action.

Subsequent Developments

The packer was lowered in Well 2 from 150 ft to 190 ft below the surface. The water from the well was reported to be poorer in quality than before. Production was reduced by 33 per cent, and further attempts to correct the well were abandoned. Drilling was begun on Site 5. Well 5 was completed as an artesian well flowing 195 gpm. The iron content is objectionably high, indicating probable proximity to the proposed fault extending from the mine southeast toward Well 5. The analysis of this site had considered the possibility of the fault zone as a probable channel for penetration of mine water into a well bore at Site 5.

Summary and Conclusions

Past drilling and production in this area met with mixed results and encountered many problems that could have been avoided by using geologic information to pick proper well locations. Subsequent operations using such information provided better results. If better records had been compiled of the wells previously drilled, the whole problem could have been more effectively handled; such records were limited to depth, rated capacity, and casing information.

Knowledge of local surface geology and structural geology, accompanied by a thorough investigation of the mining history, drilling logs, and well production history, can aid considerably in the maximum development of ground water supplies in other areas. The lack of accurate data is obvious in most areas where development has been primarily concerned with the completion of a well. Not enough attention is given to collecting and analyzing all available geologic, drilling, and production information. The need for better well records, with accurate information of the penetrated strata, is obvious. Mines, both strip and deep, can cause damage to a ground water table by collecting waters that become contaminated, then penetrate the subsurface. Some mines, however, can serve as an excellent means of artificially recharging the ground water reservoir.

Acknowledgments

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Sand Filtration of Algal Suspensions

Jack A. Borchardt and Charles R. O'Melia

A paper presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by Jack A. Borchardt, Prof. of San. Eng., and Charles R. O'Melia, Research Asst., both of Univ. of Michigan, Ann Arbor, Mich.

CONCENTRATION and subsequent examination of samples taken from treated and filtered water may show the presence of suspended impurities. Such materials as activated carbon, finely divided calcium carbonate, and substances of a biologic origin have been found in filtered effluents. Algae, as an example, have been found in the filtered water of such cities as Chicago [1] and Chanute, Kan.[2] Hobbs [3] notes several forms of algae as having passed through filters. The fact that these materials are not observed more frequently in filter effluents can be ascribed to the fact that microscopic examinations of filtered water are not often performed.

The observation of these and other suspended materials in filter effluents leads to speculation regarding filter performance. Do filters tend preferentially to remove certain forms of turbidity? Can removal characteristics be assigned to substances having coagulating tendencies, and will they differ substantially from the removal characteristics of those particles that may be classed as nonflocculent particulate matter? Is there an interaction between these two types of particles within the interstices of the filter bed? If so, is there a stoichiometric relationship involved?

Experimental investigations designed to clarify these points have been undertaken at the University of Michigan Sanitary Engineering Laboratories. This article discusses the investigations made there to date.

An investigation of the literature has indicated that few data are available on the ability of sand beds to remove algae from suspension. A controlled laboratory test capable of fixing and maintaining the type and density of algae applied to the bed should lead to an extension of knowledge in this area.

The initial experiments were directed towards an evaluation of the filtration of plain algal suspensions through sand beds. Subsequent tests have been conducted using a filter influent composed of both algal and flocculent particles. Such independent variables as sand size, flow rate, bed depth, and type and density of algae have been controlled. Their corresponding effects on bed penetration, head loss, and efficiency of removal have been observed.

Experimental Apparatus

Two laboratory filters were constructed of plexiglas tubes having an inside diameter of $3\frac{3}{8}$ in. and a wall thickness of $\frac{3}{16}$ in. Two 4-ft sections were flanged and then bolted together to form an 8-ft column. An additional 5-in. length of the same tubing was bolted to the bottom of the column

to support a porous plastic underdrain. The filters, designed for use with a 24-in. sand bed, have manometers and sampling points placed at the sand surface and at depths of 1, 2, 3, 6, 12, 18, and 23¼ in., as well as at the effluent side of the underdrain. A sketch of the filter assembly is shown in Fig. 1.

The sand used in these experiments consisted of graded Ottawa sand divided into three fractions. The results of standard size measurements on these fractions are shown in Table 1.

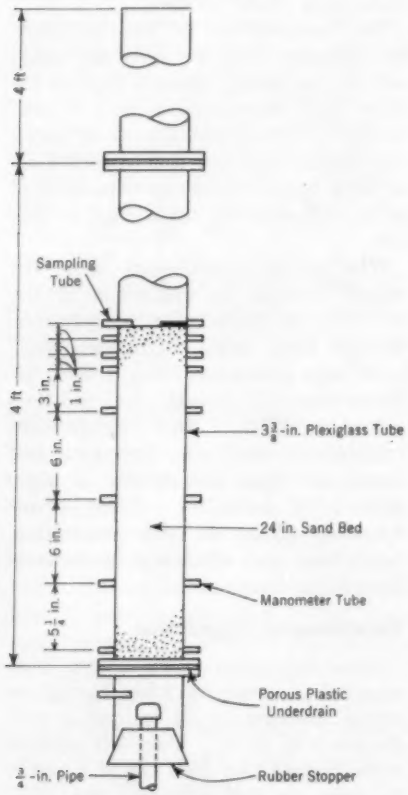

Fig. 1. Model Filter

Two such filters were used for the experiments.

TABLE 1

*Sizes of Sand in Filters**

Sieve Fraction	Manufacturer's Rating mm	Hazen's Count and Weight mm	Microscopic Measurement mm
−30 +40	0.503	0.513	0.524
−40 +50	0.358	0.390	0.397
−50 +60	0.273	0.310	0.316

* Specific gravity of sand is 2.65.

Rose [4] has stated that the ratio of the tube diameter to the sand size must be at least 50:1 to minimize effectively wall effects on the flow process. A comparison of the filter diameter to the largest sand size used indicates that the minimum value of this ratio in these experiments is 164:1.

Bed porosities have been computed from the weight of the sand placed in the bed, the specific gravity of the sand, and the total volume of the bed. It was found that the porosity obtained by allowing the sand particles to settle after backwashing varied with the size of sand used. As a result, all runs have been made using sand beds that have been compacted to a porosity of 40 per cent by gently tapping the sides of the filters after backwashing.

Algae of the genera *Scenedesmus, Ankistrodesmus,* and *Anabaena* have been grown in batch cultures in a 200-liter tank. Tap water is mixed with inorganic salts to provide the growth medium. Air is continually passed through the culture to provide carbon dioxide and mixing. Temperature control is also provided.

A schematic diagram of the entire apparatus is shown in Fig. 2. Coagulated and filtered water is stored in the settled water storage tank to allow it to reach a constant temperature. It is then pumped through a prefilter to a constant head tank. From here the

water flows through an orifice to the mixing tank. A wide range of flow rates can be obtained by adjustments in the size of the orifice or the head in the constant head tank. The overflow is returned to the storage tank.

Algae from the batch culture are introduced into the mixing tank through two inlets. One inlet provides a continuous flow of algae at a level slightly less than that required. Flow of algae through the second inlet is regulated by a solenoid valve actuated by the microphotometer which, in turn, responds to the algal density. The algae and tap water are mixed with a magnetic stirrer and the resulting suspension is passed through the microphotometer to the distribution box. A continuous recorder is used to register the density of the algae suspension as measured by the microphotometer. Accidental deviations from the desired level are discernible by an inspection of the recorder chart.

The rate of flow through the filters is regulated by orifice in combination with a float-operated valve placed in the effluent line of each filter.

Experimental Measurements

Determinations of the head loss pattern throughout the sand beds were made using the piezometer connections indicated in Fig. 1. Readings were generally taken every 2 hr throughout a run. At the same time, the rate of flow through the effluent orifice of each filter was determined.

Algae samples were withdrawn from the nine sampling points throughout each run, generally at 4-hr intervals. Precautions were taken to avoid jarring; the rate of flow through each sampling point was held to less than 2 ml/min.

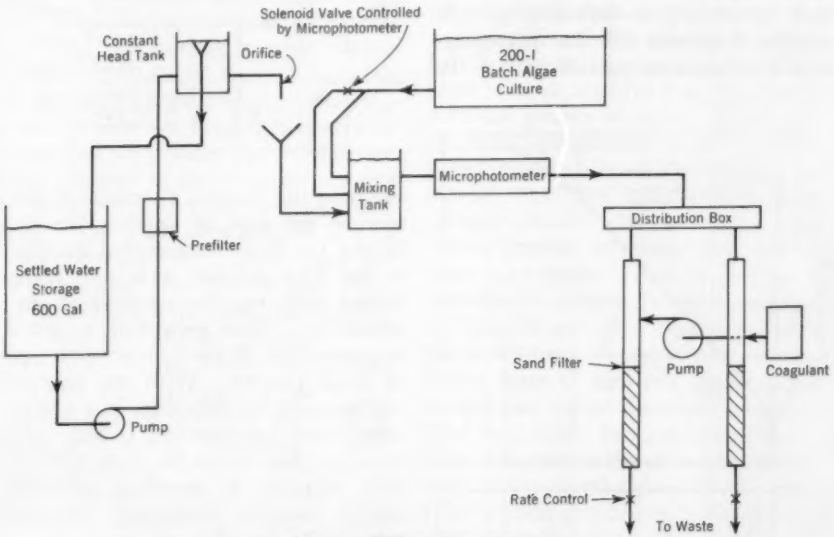

Fig. 2. Filter Apparatus

Algae concentration, head, and coagulant were controlled by the apparatus shown.

The algae samples were counted with an electronic particle counter developed primarily for use in the counting of blood cells.[5, 6] Its advantages over microscopic counting lie in its high speed and precision. Algae samples that would have taken an hour to count accurately with a microscope were counted in less than 5 min with the instrument used. It enabled the algae samples to be counted immediately and without preservation.

Although the instrument has been used successfully to determine particle volume, it appears that this determination is affected by particle shape. In addition, the counter is unable to determine the type of particle present. It was for these reasons that samples of the filter influent were also taken during each run for microscopic examination. This permitted a visual determination of the amount and type of algae present. With the unialgal culture used, no difficulties in counting were ever encountered. The unit, however, has not as yet been successfully adapted to counting naturally mixed samples containing different types and sizes of organisms.

Runs have been made during which iron coagulant was applied to one of the filters. Samples for iron determination were withdrawn from the bed using the same procedures described for obtaining algal samples, except that the collections were made at 8-hr intervals. The iron concentration in the samples was determined in accordance with the tenth edition of *Standard Methods*.[7] Both the phenanthroline and tripyridyl procedures have been used.

TABLE 2

Minimum Algal Removal Efficiencies of 42-in. Deep Sand Beds

Flow Rate gpm/sq ft	Sand Size—mm			Run No.	Algal Genus
	0.316	0.397	0.524		
	Removal Efficiency—%				
2.0	36	30		11	*Scenedesmus* (4- & 8-cell packets)
	45	34		12	*Anabaena*
			2	20	*Ankistrodesmus*
			5	21	*Ankistrodesmus*
			9	22	*Ankistrodesmus*
1.0	37	28		13	*Scenedesmus* (8-cell packets)
	23		23	14	*Scenedesmus* (8-cell packets)
	21	28		15	*Scenedesmus* (4-cell packets)
		6	3	16	*Scenedesmus* (4-cell packets)
0.2	33		17	17	*Ankistrodesmus*
		10, 8		18	*Ankistordesmus*
		26, 31		19	*Anabaena*

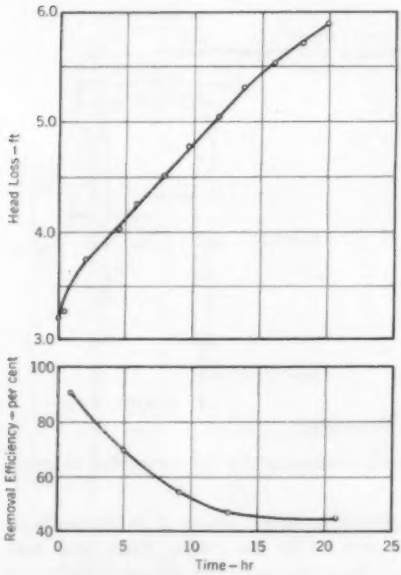

Fig. 3. Head Loss and Algae Removal During 21 hr

Data from Filter 2, Run 12, was used for these curves. Sand size was 0.397 mm; flow rate, 2.06 gpm/sq ft; algal genus, Anabaena; *algal concentration, 149,100 particles per milliliter.*

Results

The changes in head loss and particle removal that occurred across a filter treating water containing *Anabaena* alone are shown in Fig. 3. It can be observed that the percentage of algae removed by filtration decreases rapidly with time during the initial stages of the run. Removal then decreased at a more gradual rate, eventually reaching a constant minimum value of 45 per cent. Significant quantities of *Anabaena* were found in all the filter effluent samples. The rate of head loss increase appears to decrease slightly with time at the start of the run. After 2 hr, a linear relationship between head loss and time exists for the greater part of the run. Near the end of the filtration the rate of clogging began to decrease with time. The data presented in Fig. 3 were observed for a 24-in. sand bed having a sand size of 0.397 mm filtering a suspension of *Anabaena* particles at a flow rate of 2.06 gpm/sq ft.

Variation of the parameters of sand size, flow rate, and algal genus in this research always produced results that, although differing numerically from those presented in Fig. 3, exhibited similar trends. These may be summarized as follows: (1) algal removal was found in every case to decrease with time to a constant minimum value, (2) significant numbers of algae were found in every effluent sample taken throughout the research, and (3) head loss increase was linear with time throughout the greater part of each run.

A tabulation of the minimum removal efficiencies observed in twelve filter runs on the two model filters is shown in Table 2. The size of sand appears to have a distinct effect on removal. Averaging the results obtained for each sand size indicates that minimum removal efficiencies of 33, 22, and 10 per cent were produced by sand sizes of 0.316, 0.397, and 0.524 mm respectively. On the other hand, considering the data obtained for the various sand sizes at each flow rate, no difference in removal can be noted between flows of 2.0, 1.0, and 0.2 gpm/sq ft. Unfortunately, the limited amount of data obtained does not permit a more quantitative estimation of the effects of these variables.

Dispersion of the data from run to run is evident. Some of these differences can be attributed to the use of different genera of algae. For example, it is apparent that the stringy *Anabaena* gives consistently higher removals than the smaller and more compact *Ankistrodesmus*. Variations within genera, however, are also of some magnitude. This dispersion is particularly evident in a comparison of Runs 15 and 16. These runs were conducted using *Scenedesmus* particles in the form of four-cell packets, and in each run, one of the filters contained 0.397 mm sand. It would seem, therefore, that despite the care and control used in the development of the filter influent from run to run, some characteristics of the algal cells has produced significant variations in the results obtained.

Table 3 summarizes the head loss produced across the two filters during twelve runs. The sand size, flow rate, algal genus and concentration are shown for each case. It can be seen that where no coagulant is used, relatively little head loss is developed, although normal lengths of filter runs were employed. It should be recalled that all filter runs involved the passing of substantial and increasing amounts

of algae with time. An analysis of the data shows that the initial head loss across the beds is directly proportional to the flow rate and inversely proportional to the square of the sand size, indicating the existence of laminar flow. A definite relationship defining the effects of these variables on the final head loss cannot be developed from the existing data, because of the variations in removal experienced from run to run.

In Fig. 4, the percentage of algae remaining in suspension is shown at any given depth in a filter bed operated at a slow sand filter rate and for various times throughout the run. The results indicate that about 40 min after the start of the run, 25 per cent of the *Anabaena* applied are passing the bed. Similarly, at 8.6 hr 52 per cent pass the bed; at 20.8 hr, 58 per cent; and at 45–56 hr, 67 per cent of the applied algae are passing the bed. The curves indicate that with time, increasing percentages of algae pass the bed at all levels of bed depth. No apparent change in removal is evident at the bed surface. Curves of a similar nature were observed for runs conducted with different algal types, sand sizes, and flow rates.

Examination of the last three runs of Table 3 shows the attempts pres-

TABLE 3

Head Loss, Coagulent Use, and Other Variables

Run No.	Sand Size *mm*	Flow Rate *gpm/sq ft*	Head Loss—*ft*			Length of Run *hr*	Algal Concentration *Particles per ml*	Algal Genus
			Initial	Final	Increase			
11	0.397	2.08	2.03	2.47	0.44	28.7		*Scenedesmus* (4- &
	0.316	2.07	2.94	3.62	0.68	28.7	49,500	8-cell packets)
12	0.397	2.13	2.19	3.62	1.43	19.9		*Anabaena*
	0.316	2.06	3.19	5.90	2.71	19.9	149,100	
13	0.397	1.13	1.14	1.28	0.14	19.6		*Scenedesmus*
	0.316	1.13	1.67	2.06	0.39	19.6	90,000	(8-cell packets)
14	0.524	1.10	0.685	0.873	0.188	24.0		*Scenedesmus*
	0.316	1.05	1.74	2.34	0.60	24.0	96,000	(8-cell packets)
15	0.397	1.01	1.11	1.37	0.26	24.3		*Scenedesmus*
	0.316	0.98	1.60	1.93	0.33	24.3	151,800	(4-cell packets)
16	0.397	1.05	1.20	1.30	0.10	19.5		*Scenedesmus*
	0.524	1.00	0.584	0.634	0.050	19.5	177,100	(4-cell packets)
17	0.316	0.170	0.308	0.798	0.490	50.7		*Ankistrodesmus*
	0.524	0.192	0.105	0.243	0.138	50.7	243,000	
18	0.397	0.208	0.237	0.543	0.306	69.2		*Ankistrodesmus*
	0.397	0.153	0.227	0.453	0.226	46.3	243,900	
19	0.397	0.199	0.225	0.311	0.086	55.6		*Anabaena*
	0.397	0.163	0.171	0.257	0.086	55.6	86,360	
20	0.524	2.09	1.15	2.86	1.71	20.6		
	0.524	2.07	1.02	1.21	0.19	20.6	350,800	*Ankistrodesmus**
21	0.524	2.15	1.34	1.66	0.32	11.0		
	0.524	2.09	1.18	1.28	0.10	11.0	329,300	*Ankistrodesmus*†
22	0.524	2.13	1.20	7.05	5.85	12.8		
	0.524	2.16	1.18	1.51	0.33	12.8	266,000	*Ankistrodesmus*‡

* With 0.98 ppm iron. † With 0.92 ppm iron. ‡ With 7.15 ppm iron.

ently being made to incorporate the additional variable of a chemical coagulant in the work. Runs 20 and 21, using an iron floc at a level of approximately 1 ppm iron, show very little additional head loss induced by the coagulant. At this point the iron was increased to 7.15 ppm and the algal density was reduced. Figure 5 shows the results obtained from the two separate but identical filter units. Filter 1 received both algae and iron floc while Filter 2 received algae alone. In all respects Filter 2 responded as would be predicted with results from previous runs. The sand used was fairly coarse and the percentage of algae passing the bed was above 90 per cent for most of the run. The head loss increase was very low.

Filter 1, on the other hand, received a substantial amount of chemical floc and the head loss trend shows an exponential increase. The percentage of algae remaining in the effluent of Filter 2 was substantially higher than that of Filter 1, but it should be noted that 48 per cent of the algae was still left in the effluent of Filter 1.

In Fig. 6, the relationship is shown between the percentage of iron remaining and bed depth, as was previously shown between algae remaining and depth in Fig. 4. The similarity in the graphs is striking. The curves indicate that as time increases, a continually increasing quantity of iron remains in the filtrate at any given depth. Unfortunately, the head loss through the filter was also increasing rapidly. Consequently, the maximum capacity of the bed for holding the chemical floc could not be reached because of limitations imposed by the head loss developed in the apparatus.

It is also possible to plot on the same curves the particles remaining at various depths. This plotting indicates that both algae and chemical floc particles exist in the upper bed levels. As no iron passed out of the filter bed, the particles remaining at 24 in. of bed depth are all algae. Examination of the continuity of the curve for 0.8 hr, for example, indicates that algae are the only particles being counted through the lower 16 in. of the bed. At the 8-in. depth a sharp break indicates the presence of both algae and floc particles. The iron percentage also indicates that such a conclusion is logical. Examinations at other times show similar trends. It is apparent that where iron and algae are present together, extraction of the algae is enhanced. Similarly, after the iron has been extracted by the upper layers of the filter bed, the removal of algae falls

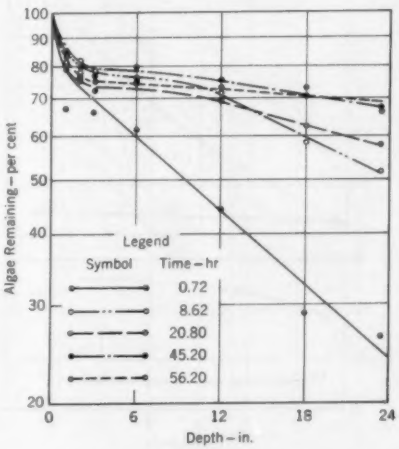

Fig. 4. Algae Remaining in Suspension at Various Bed Depths

Curves were made from data of Run 19, Filter 2. Sand size was 0.397 mm; flow rate, 0.163 gpm/sq ft; algal genus, Anabaena; *algal concentration, 86,360 particles per milliliter.*

to that rate characteristic of a bed with no chemical floc. The fact that the algae and floc were originally mixed together has apparently not changed the filtering characteristics of those algae that have passed out of the floc zone and into the lower levels of the filter bed.

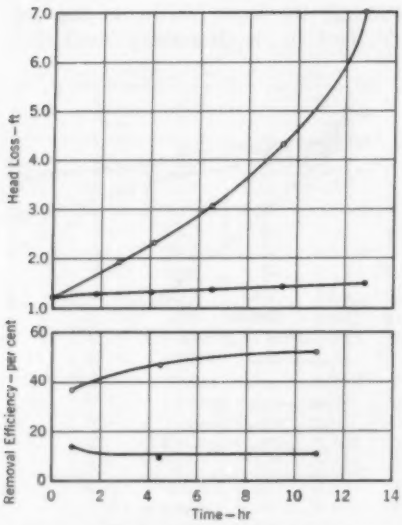

Fig. 5. Head Loss and Algal Removal During 13 hr

Circles represent Filter 1, in which sand size was 0.397; flow rate, 2.13 gpm/sq ft; and iron concentration, 7.15 ppm. Dots represent Filter 2, in which sand size was 0.397; flow rate, 2.16 gpm/sq ft; and no iron coagulant added. In both filters, algal genus was Ankistrodesmus *in concentration of 262,000 particles per milliliter.*

Discussion

Previous studies of the filtration process have been based on measurements of such parameters as: (1) time rate of clogging as measured by head loss increase, (2) bed penetration, (3) turbidity removal, and (4) length of filter run. These all have direct application to the actual filtration process and thus have meaning to all water production personnel. Similar parameters have been used in this study.

Evidence from the results obtained to date in this research indicates that algae are removed by a filter bed at a different degree from that at which flocculent material is removed. When an algal suspension is filtered, a low percentage of the algae is removed by each increment of the filter bed depth. The result is that some of the initial material leaves the bed continuously. This amount increases with time as the available sites for removal are used up. If algae can be considered as nonflocculent material, it seems reasonable to expect such materials as calcium carbonate and activated carbon to behave in a similar fashion.

In contrast, no iron floc was detected leaving the bed in the duration of the runs studied. It should be noted that the pattern of penetration observed in Run 22 is quite similar to that observed by others [8, 9] in studying iron floc penetration into filters.

From the dispersion of results in Tables 2 and 3, it seems apparent that some other variable or variables must play a part in the process of algae filtration. This factor might well be density, surface charge, or some other parameter originating in the algae cell itself. While the organisms used were basically of the same age (10-day cultures) and all grown on an inorganic medium, physiological differences in the cells were sometimes noted. *Scenedesmus* cells frequently started out as 8-cell packets, then dropped to 4-cell packets. No microscopic changes were ever noted in *Ankistrodesmus* and only

minor differences in length were noted in the *Anabaena* cultures.

From the shape of the removal curves it can be deduced that functionally, the behavior of the filter bed is the same in the removal of either type of particle (flocculent or nonflocculent). Some surface straining takes place, followed by continuous uniform removal with depth. If the rate of removal is high (as with flocculent particles), percentages of particles reaching the lower levels of the bed are insignificant. But if the rates of removal are low (as with nonflocculent particles) percentages of particles reaching the lower levels of the bed are substantial. Presumably, if the filter beds were sufficiently deep, good removals of algae alone could be obtained. Such bed depths are, however, impractical.

The difference in the rate of extraction is also a matter of some interest. Either the bed has a high affinity for the iron or the iron particles have an affinity for each other. Stanley's work [8] suggests that iron is removed best at its isoelectric point. From this it seems that strong mutual agglomeration between the floc particles must be the best explanation for their high rate of removal. Additional support for this conclusion comes from the work of Sanford and Gates.[10] Their research indicated that a shift in the charge of the sand grains from negative to positive produced no change in the removal of alum floc or *Esch. coli*. The mechanism of the process apparently is that the interstices of the bed act as conductors directing the floc particles past each other, enhancing the growth possibilities, then supply voids in which to store these enlarged particles.

The filter bed provides these same voids for storage of all kinds of particles. In this study, the iron floc and the algae cells proved to have sizes that were approximately the same. Some form of growth of the floc particle seems necessary to explain the comparatively high floc removal values. The storage of enlarged floc results in an increase in head loss which forces lateral motion to take place and makes possible the use of the maxi-

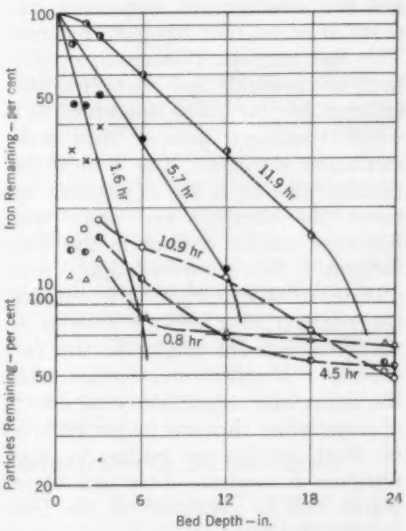

Fig. 6. Total Particles and Iron Remaining in Suspension During 24 hr

Curves were made from data of Run 22, Filter 1. Sand size was 0.397 mm; flow rate, 2.13 gpm/sq ft; algal genus, Ankistrodesmus; *algal concentration, 226,000 particles per milliliter; iron concentration, 7.15 ppm. Particle concentrations are computed assuming the applied algal concentration is 100 per cent.*

mum number of storage sites before the floc moves downward in the bed.

Apparently this type of growth and subsequent storage is impossible for nonflocculent particles. The presence of flocculent material assists in the entrapment of algae cells, but an adequate balance between the chemical and the nonfloccuent suspension appears to be vital for complete removal. This fact suggests that multiple additions of chemicals and controlled flocculation are far more important to a water treatment process than sedimentation capacity. The critical parameter may lie in the adjustment between the chemical and other nonflocculent matter present in the filter influent. Where overloading, poor mixing, or short circuiting is possible, the addition of chemicals directly to the filter influent might be the best remedy. Further investigation into the nature and magnitude of the effects of coagulating chemical on the removal of inert particulate matter in sand filtration is needed. This type of research will be continued at the University of Michigan.

Acknowledgments

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Removal of Algae by Microstrainers

Albert E. Berry

A paper presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by Albert E. Berry, Gen. Mgr., Ontario Water Resources Com., Toronto, Ont.

MICROSTRAINERS have now been in use for a considerable length of time, operating under a variety of conditions. This article will review some of the experiences obtained from these installations and will comment on operating problems and the circumstances under which this treatment may be successful. A number of installations have been in service for some time in Canada, and the results obtained here are recorded along with comparisons of Canadian installations with units in other parts of the world.

There is and must be a continuous search for means to remove effectively and cheaply any solids or substances considered undesirable in the potable product or the industrial supply. Means are also being sought to remove effectively the substances that tend to choke water filters. Microstrainers were developed to serve both of these purposes, and they have been used in numerous places as the only filtering process, or as a strainer to eliminate interfering substances ahead of sand filters. How this is accomplished and the problems arising from it are significant if full use is to be made of modern purification processes.

Today's microstraining is based on developments in microfabrics of stainless steel to produce apertures of 23–65 μ. About 15 years ago, the first installations were made in England to provide for the removal of algae ahead of slow sand filters. Much experimental work has been done since then, and records are available from many plants. This and studies on the clarification of sewage effluents and industrial wastes have added to the knowledge of what can be accomplished with microstrainers, where they can be used to advantage, and some of the difficulties likely to be encountered. Units are now operating in many parts of the world.

Construction of Microstrainers

The construction and function of the microstrainer needs to be understood to avoid operating difficulties. This rotary drum type of equipment with the filtering fabric on the periphery receives water by axial flow into one end of the drum, and passes it out radially through the fabric. The intercepted solids are thus retained on the inner face of the fabric. Rapid self-cleansing takes place as the drum rotates. This continuous backwashing is necessary to prevent blockage and increase in the filtering head, usually set at 1.5–5 in. The drums rotate continuously at speeds up to a maximum peripheral velocity of 100 fps. The filtering action thus depends on the size of the apertures and the thin mat of algae or debris which forms on the

surface. The material washed from the fabric goes to a waste hopper inside the drum and from there to waste.

The driving unit of an electrically driven, variable-speed, hydraulic mechanism can be adjusted while running, either manually or automatically. The speed of rotation can be synchronized to the head loss, and automatic by-pass weirs can be incorporated into the design to permit full flow to take place at times of failures or temporary overloading. Thus the design can include all modern controls to suit the conditions likely to be encountered in supplying water to the system.

These units are built in standard sizes with a wide range of capacities based on filtration rates of 600–2,000 gal (Imp)/sq ft/hr. The diameters vary from 5 to 10 ft, and the effective widths from 0.5 to 15 ft. The motors required range from 0.5 to 6 bhp. The approximate range of capacity of these units is from 50,000 gpd (Imp) to 15 mgd (Imp).

Selection of the appropriate size of unit must be based on a number of factors, each of which is to be determined in advance by the designer and supplier. In addition to such items as rate of flow and mechanical features, the filtrability index of the water is most important, as it is a measure of the rate of increase of hydraulic resistance of the filtering fabric at a constant velocity of approach. If this is not determined, the capacity of the unit may not be anticipated. Furthermore, greatest capacity can be achieved only when the maximum submergence of the drum is obtained. Variations in water levels at the intake end must be reduced to a minimum. These are some of the conditions that apply to the design and installation of units. It is important to have reliable information on the water and on local requirements before the design is undertaken.

Use of Microstrainers

As this device has now been in use long enough for a good evaluation to be made, it is well to examine the use already made of it, the objectives of these installations, and the records of their achievements. The author has direct information on those in Canada, and the details of others[1, 2] have been published. Efficiency studies and operating records have been made in some detail for the installations in Ontario, where algal growths have become more troublesome and more voluminous in recent years. In Ontario, eight installations are either in operation or will be in use shortly. They are at Belleville, Harrow, Union (near Leamington), Dunnville, Bertie Township, Brockville, Campbellford, and Hastings.

Microstrainers are reported to be in use in England, the United States, Japan, South Africa, Australia, New Zealand, Sweden, Czechoslovakia, Canada, and many other countries. Hundreds of these machines are processing many hundreds of millions of gallons per day. They are used on drinking waters and on industrial water supplies. They serve as the sole filtration, as treatment ahead of both slow sand and rapid sand filters, as filters of sewage and industrial effluents after treatment, and as devices for certain other miscellaneous uses. These uses make a reasonable evaluation possible at this time.

In Canada there are fifteen installations either in use or to be in use shortly. Of this total, thirteen are serving as the only treatment apart from disinfection; two are used ahead of rapid sand filters; and some are

pilot units. Six of these installations are projects of the Ontario Water Resources Commission. Here it is possible to conduct tests on them and to observe all operating problems closely.

The figures for Canada show that nearly all microstrainers are used as the sole means of removing solids from the water. The choice in most instances would have been based on the cost as compared with that for filtration, and on the fact that no high amount of silt or suspended solids was present. Under these conditions there should be a substantial saving in cost.

In the other two installations, one on the Union system, and the other at Belleville, the units precede mechanical filters. The former takes water from Lake Erie, and the other draws water from a bay which for many years has had a history of heavy seasonal algal growths that seriously interfered with filter operation.

In the United States, at the end of 1960, there were twelve plants in operation or under construction. Three of these used units 10 ft in diameter and 10 ft in width. Some have been tested extensively and the resulting efficiencies are a matter of record.[1]

Operating Results

The selection of microstrainers for water treatment must be related to their efficiencies in removal of algae and to their economics in comparison with other methods of treatment. The designer needs this information in deciding on the method of treatment to be used. The experiences in the plants in Ontario are cited to illustrate what may be anticipated under conditions like those in the Ontario plants.

The Belleville unit was the first to be installed. It consists of four 7-ft 6-in. diameter, 5-ft wide machines with Mark 1 fabric and a maximum flow of 8 mgd. The water is treated by rapid sand filters. In the summer months the heavy algae blooms caused great difficulties in operating the filters, and a minimum filter run of 2 hr was encountered. Much water was needed for backwashing the filters, and the capacity of the filtration plant was greatly reduced at a time when consumption was highest. The unit went into operation in June 1958, after work carried out during the previous summer on a pilot unit. The algae consist mostly of a number of lake type diatoms (*Melosira, Tabellaria, Fragilaria, Asterionella*) that live in varying numbers throughout the year, together with a high population of blue-green algae (*Anacystis, Anabaena, Aphanizomenoa*) during the warm-water period. A series of nine investigations have been made over a period of years to determine the effectiveness of algal removal. In all these determinations the average reduction was 89.3 per cent of the net plankton (net plankton is defined as those algae of sufficient size to be retained on passing the water through No. 20 bolting silk).

A comparison of results obtained in the operation of the Belleville water plant in 1957 with results from 1959 reveals some interesting information apart from algal removal itself. The total washwater, including that used for the microstrainers, dropped from 9.7 per cent to 5 per cent, of which 2.7 per cent in 1959 was for the microstrainers. The yearly frequency of filter backwashes decreased from 1,074 to 262, and the average filter runs increased from 14.3 hr to 52.3 hr. The average loss of head on the filters was reduced from 6.5 ft to 4.4 ft. The

consumption of aluminum sulfate was also reduced from 91,900 lb in 1957 to 29,900 lb in 1959. These results left little doubt about the efficacy of the installation under the conditions found in that water. The approximate cost of this installation, including the extension of the building to house the units, was $150,000, or $18,700 per mgd capacity.

The Brockville water supply is taken from the St. Lawrence River, a supply that does not have much turbidity but might carry algae periodically. As the former intake site was to be abandoned for a new location of the supply facilities, the consulting engineer had to determine whether he would recommend filtration or microstraining. He chose the latter. The installation consists of three 7-ft 6-in. diameter, 5-ft wide units intended to handle 7.5 mgd, and with provision for doubling this capacity. Mark 1 fabric is employed. The installation was put into service in 1960, and details on its efficiency in algal removal during the season of high algal concentration have not been determined. The cost of this installation involving all parts required for microstraining was $700,000, or $93,000 per mgd, with this factor to be lowered as the capacity is increased.

Two other installations, both taking Lake Erie water and both constructed by the Ontario Water Resources Commission, are at Harrow and at Union. The former installation is a unit 7 ft 6 in. in diameter and 5 ft in width. It was placed in operation in August 1958. No filtration plant is in use, although turbidity in time of storms is somewhat objectionable. Cost was the deciding factor in omitting the filters for the present. This plant has been effective for algal removal. It has a designed capacity of 1 mgd. It has Mark 0 fabric.

At the Union plant, one microstrainer 10 ft in diameter by 10 ft wide and having Mark 1 fabric was put into service in November 1960. The design capacity is 8 mgd. From the microstrainer, the water goes to a modern, automatic, mechanical sand filtration plant. The raw water quality here is about the same as that at Harrow.

Plans have recently been made for algal enumeration, and routine determinations before and after microstraining will shortly be available. A mechanical failure occurred recently, necessitating the bypassing of the microstrainer, and an immediate decrease was noted in the length of filter runs.

These units operating in Ontario under close contact of the Water Resources Commission provide useful information under the different circumstances encountered.

Operating Problems

Apart from the efficacy of microstrainers in removing algae, other information on operating problems and costs is to be noted. Difficulties have been encountered in some of the installations in Ontario. Some of these might have been avoided or minimized had the present information been known at the outset.

Difficulties arose in some cases from the design and construction of the units. Some units had inadequate means for controlling abnormally high heads, thereby damaging the fabric and causing early costs for replacement. Automatic controls in the first instance did not effectively adjust washwater pressures and speed of rotation of the

drum. A problem also arose with the drive mechanism that was not supplied by the manufacturer of the microstrainer, and did not meet the needs. Unfamiliarity with the operation of the equipment also created problems. It was clear from these experiences that in any such installations all parts should be fully in accord with the specifications of the manufacturer, or else some parts might not prove suitable. Where difficulties did arise, the manufacturer cooperated fully in making adjustments, and it is believed that these mechanical problems can be avoided in the future.

Sliming and blinding of the fabric were other problems to be overcome. Sliming was first experienced in the Belleville plant during the winter. An effective solution was not readily available. The slimes could not be controlled by backwashing, and only with some inconvenience by sodium hypochlorite or other chemicals. Ultraviolet radiation was found to be the most effective means for slime removal in the units in Ontario. It has now been found desirable to equip all the units with ultraviolet lights and to operate them continuously. Some difficulty was also experienced with the efficiency of the lights themselves, but with proper ultraviolet light radiation this bacterial growth appears to be kept under control.

Blinding of the fabric from causes other than slimes may be encountered. An unexplained phenomenon has occurred at several installations when a notable loss in capacity developed. This condition is associated with cold water, and air binding is considered to be a possible cause. Further studies will be undertaken next winter to determine the reason for this loss of capacity and to develop an effective solution.

Cost Data

Microstrainers have the distinct advantage that the capital charges and operating costs are considerably lower than those for filtration. It is not equitable to compare these two processes on an even basis because they accomplish quite different results. There are many places, like those referred to in Ontario, where filtration would serve chiefly to remove algae and debris that can be effectively eliminated by microstrainers. Similarly, the capacities of filter plants, as at Belleville, can be increased by the use of this device, and further expenditures delayed. Installation costs will vary from place to place depending on a number of circumstances. The operating costs are quite low, almost to the point where they are relatively insignificant. The costs of repairs and maintenance are difficult to determine. It is hoped that if the mechanical equipment and design are adequate in the first place, maintenance can be kept within reasonable limits. Time will enable more information on this to be compiled.

Other Uses of Microstrainers

In Ontario there has been an interest in the use of microstrainers for purposes other than treatment of public water supplies. One of these possible uses is the polishing of sewage effluents. Where these effluents must go into small streams, as is so often the case, it is essential that the solids and BOD be reduced to as low a point as possible.

The Ontario Water Resources Commission has carried out studies on

treatment of the effluents from activated sludge plants for 2 years. The results of these tests have indicated that on an activated sludge plant effluent having suspended solids ranging from more than 50 ppm to a few parts per million, the microstrainer gave a reduction of over 50 per cent and maintained the final figure at about 20 ppm. Similarly, with BOD varying from 7 ppm to as much as 190 ppm, the reduction averaged over 50 per cent. These results are encouraging because they show that the unit with Mark 0 fibre was effective in substantially reducing both BOD and suspended solids. These results can be applied to advantage under certain conditions of rigid stream sanitation.

Conclusion

During the 15 years since the method was first established, microstrainers have proved their value under prescribed conditions. They are effective in the removal of algae; the cost of treatment is normally low; they can be used either as the sole treatment for community and industrial water supplies, or they can be a valuable primary treatment ahead of filtration. Care is needed in the evaluation of conditions where they can be expected to prove of service, and the design of the installation should be in accord with what has been found to be satisfactory. Intelligent operation is also required. Microstrainers give promise of being helpful in the treatment of sewage effluents, and in other ways of removing substances from water economically. Their use as an economical aid in purification processes needs to be explored fully.

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Improved Operation of Four Treatment Plants at Detroit

Albert M. Shannon

A paper presented on Jun. 8, 1961, at the Annual Conference, Detroit, Mich., by Albert M. Shannon, Chief of Water & Sewage Treatment, Dept. of Water Supply, Detroit, Mich.

THE Detroit department of water supply is a municipally owned utility that provides water supply and sewage treatment services to the Detroit metropolitan area. By contract agreements, beneficial to both the suburb and central city, the area-wide water problem has been solved, and the area-wide sewage treatment problem is being solved on the same basis.

Transmission mains to each suburban area in three counties have been, or are to be, financed and constructed by Detroit. No tax money is used; all financing is done with revenue bonds, which can be marketed with low interest rates because the bonds carry an "AA" rating. This advantageous rating was obtained, and is preserved, by the department by maintaining an adequate level of revenues, pledging the revenues of the entire system, and retaining the authority to set rates. The department has thus been able to build filtration plants, pumping stations, and transmission mains, and to expand the service area to any community in the metropolitan area that desires water. Engineering studies, however, must show that an adequate load exists or that there will be an adequate load in the near future. It is believed that the operation of one major utility in the area will result in more reliability, better supply, less duplication, and lower average costs.

Board of Water Commissioners

The control and management of the department has been chartered in the board of water commissioners since 1853. At that time, special powers and authority were granted to this body to develop the water system and to accomplish necessary improvements. The board now consists of seven citizens appointed by the mayor of Detroit to serve without compensation for terms of 4 years. Four of the members must be Detroit residents; three come from the suburbs. One of the members is required to be a mechanical engineer. The executive head of the department is the general manager.

System Developments

Water Works Park filtration plant was placed in service in 1924 and still is an important part of the Detroit system. Since then, all water used at Detroit has been treated and filtered.

Because of the rapidly increasing demand for water both in the city and suburbs, the board and general manager developed, in 1924, a long-range master plan for serving the entire metropolitan area. This included the present raw-water intake and tunnel system; Springwells Station, placed in partial operation in 1932; and Northeast Station, completed in 1956. A

provision was made for a Northwest Station; however, as a substitute, an addition to Springwells was completed in 1959, which made it one of the largest filtration plants and pumping stations in the world. By 1956, the raw-water tunnel system was approaching its maximum capacity, and, to alleviate this, a raw-water booster station in the tunnel leading to Springwells and Northeast was completed at Water Works Park in 1960.

In 1959, the general manager and the board of water commissioners presented a 20-year water development program for the metropolitan area. The program provides plans for the orderly development of water facilities for six surrounding counties—which will have a population of 5,000,000 by 1980—a Lake Huron intake with the first 250-mgd unit of an ultimate 800-mgd filtration plant, pumping stations, transmission mains to metropolitan Detroit, and storage reservoirs, as well as plans for the reconstruction and rehabilitation of present facilities. In 1960, as a part of this program, Detroit, through the board of water commissioners, entered into a lease purchase of the Wayne County water system. This system includes a newly completed raw-water intake and tunnel, distribution facilities and reservoirs, a 160-mgd filtration plant, and a pumping station now under construction in the downriver area. It is estimated that the cost of the entire program will be approximately $172,000,000, which does not include the cost of the downriver plant.

The weakness in the present Detroit system is its dependence on a single intake and tunnel system. These are reliable structurally, but if modern destructive forces with radioactivity were released in Lake St. Clair or in the vicinity of the present intake, the entire system would be impaired. The second intake downriver would be affected at the same time. Therefore, the reliability and adequacy of supply demand an upstream intake, preferably one above than the sources of industrial pollution. An intake in Lake Huron was the only logical choice. To date, consulting engineers have been engaged to locate the sites for the intake, plant, and rights of way, and to design a suitable intake.

Detroit is midway in a planned expansion program. Financing is available. As the water requirements of the area increase, additional filtration plants and pumping stations or segments of plants and transmission mains can be added in a comparatively short time, thereby creating a water system capable of meeting any load requirement.

The Detroit department of water supply operates three large filtration plants and pumping stations and will operate a fourth one, when it is completed, in the downriver suburban area. Water Works Park with 80 filters is located on the Detroit River; Springwells with 108 filters, at the western city limits; and Northeast with 48 filters, at the northeastern city limits. Each filter is 0.025 acre in area. These plants supply water to approximately 3,200,000 people in Detroit and 50 suburban communities, about 41 per cent of the population of Michigan. Contract negotiations have been or are being concluded with several other suburbs.

All the present water treatment plants are served by a common raw-water intake located where Lake St. Clair joins the Detroit River. This site was selected after thorough surveys showed that approximately 5 bil gal/hr of the best quality water in this area was flowing down the ship

channel through Lake St. Clair. Even during peak-hour demand, only 1 per cent of this flow is diverted through the intake. To enter the Detroit system, the raw water first must flow under booms that deflect ice, floating debris, and surface waters; through a lagoon, which is 0.5 mi long and 400 ft wide, where some settling occurs; and into two intake shafts and tunnels that run through bedrock under the river to Water Works Park, where screening and prechlorination are done. From here, the raw water travels a short distance through a tunnel system to the low-lift pumps and treatment plant of Water Works Park and also to those of Springwells and Northeast.

The elevations of these tunnels are below the bottom of the Detroit River, insuring gravity flow to the plants. A raw-water booster station recently completed at Water Works Park can increase the flow to Springwells and Northeast during periods of high demand by pressurizing the tunnel.

Filtration and Treatment

The Detroit plants were designed for a filtration operating rate of 160 mgd/acre (2.55 gpm/sq ft), with the exception of the Springwells Addition, which was designed for 180 mgd/acre (2.88 gpm/sq ft). All the filters have operated at a rate of 200 mgd/acre (3.2 gpm/sq ft) without loss of water quality. If necessary, the Springwells Addition could be operated at 250 mgd/acre (4.0 gpm/sq ft). The rated capacities of the plants are: Water Works Park, 320 mgd; Springwells, 272 mgd; Northeast, 192 mgd; and Springwells Addition, 180 mgd, or a total of 964 mgd. For peak demand periods, 1,140 mgd can be produced.

Chemical treatment at all the plants is the same; chlorine, liquid alum, and carbon slurry are used. There are large chemical industries and oil refineries at a level higher than the intake; as a result, phenolic slugs of industrial pollution, as well as other organic and inorganic pollutants, sometimes get into the raw water. Each year the chlorine demand of the raw water has increased. In order to treat this water adequately to eliminate tastes and odors and to make the water bacteriologically safe, a large prechlorination station, capable of feeding 28,000 lb/day of chlorine, was installed at Water Works Park in 1956. By adding a prechlorination dose, based on chlorine demand tests, long before the raw water reaches the treatment plants, a longer contact time is provided. This kills the coliform bacteria, satisfies most of the chlorine demand, and eliminates practically all taste and odor pollutants. Additional chlorine facilities are located at each plant to supplement the prechlorine dose, if necessary, and to serve as standby equipment in case of prechlorination failure.

Liquid alum (8.3 per cent Al_2O_3) is used as a coagulant. Detroit started using liquid alum at Springwells in 1953. This installation proved so successful that all the plants were converted to use alum in this form. Originally, it was necessary to keep the storage tanks heated to prevent crystallization. This, however, is no longer necessary. Liquid alum is delivered in tank trucks by a local supplier, stored in underground lead-lined concrete tanks, and pumped to constant-level or day tanks where it is metered by rotameters. Liquid alum has proved to be a better coagulant than alum slurry, as it is in solution and the dose can be controlled more accurately. In addition, considerable economy in purchase price and handling costs has been realized.

Carbon, which is used for taste and odor removal, is fed as a slurry. Carbon is purchased in railroad airslide hopper cars and unloaded directly into large, underground concrete tanks where it is slurried to a concentration of 1 lb/gal. The advantages of feeding carbon as a slurry lie in its cleanliness, ease of handling, low handling costs, and accuracy of feed.

Since 1924, Detroit has had uninterrupted laboratory control over filtration and treatment processes at all plants. Each laboratory is equipped with a sampling sink and observation cylinders that continuously produce samples from the important points in the treatment process. Hourly or more frequent checks and tests are made on the raw water, water undergoing treatment, plant effluent, chemical doses, feeding equipment, filter rates, and loss of head. Around-the-clock operation and supervision by professionally trained and licensed chemists or chemical engineers, together with the keeping of accurate records, have enabled these plants to meet and surpass set standards and to be operated efficiently.

Northeast and Springwells are multiple water treatment plants. Northeast consists of two, and Springswells three, separate plants beyond the low-lift pumps. Each plant has its own chemical-feeding equipment, dosing points, mixing basins, flocculating equipment, settling basins, and filters. Beyond the filters, the threads of flow merge. This allows for an opportunity to compare pretreatment results without considering the effect of design. Actually, Detroit is operating six water treatment plants, the smallest of which has a rated capacity of 90 mgd.

Water Works Park

Pretreatment at Water Works Park, the oldest plant, consists solely of coagulation with alum, followed by conventional sedimentation. No mechanical equipment of any kind is employed for rapid mixing or flocculation. The alum is added directly into the raw-water conduit just ahead of the low-lift suction chamber and centrifugal pumps. The mixing basin is an 18×18-ft conduit, 240 ft long, with baffles extending out from the walls. There are two around-the-end settling basins. The detention time is 2 hr at 320-mgd flow. Some floc formation occurs in the mixing basin, followed by some additional flocculation at the influent end of the settling basin where turbulence exists.

The reduction in turbidity through the settling basins has averaged 40 per cent, and often 20 per cent; sometimes no reduction was obtained during periods of low turbidity and temperature. The average settled-water turbidity at Water Works Park has been 9 units. This places an excessive load on the filters and increases wash water consumption and filter bed maintenance costs.

The causes for the unsatisfactory pretreatment at this plant are inadequate mixing and flocculation, nonuniform flow in the around-the-end settling basins, and the high linear velocity through the basin. Although sedimentation and pretreatment are poor at Water Works Park, a satisfactory effluent can be produced with moderate alum doses and higher-than-normal wash water consumption, provided the filters are maintained in good condition. Periodic gravel regrading and frequent surface cleaning to remove mudballs are required. Several filters have been regraded with the new gravel arrangement developed by John R. Baylis, of the Chicago Department of Water and Sewers. So far this gravel grading has proved satisfactory, and it is expected that future regrad-

ing will be done by this method. Only eight filters have surface wash, but the filter-cleaning program will continue.

High plankton concentrations rather than high settled-water turbidities are the cause of short filter runs. At Detroit, raw-water plankton are most numerous during the winter months, when coagulation is most difficult. The shortest filter runs, 12 hr, occurred in February 1960 when the raw and settled turbidities were 2 ppm and the settled-water plankton averaged more than 500 standard areal units per milliliter. Fortunately, this is also the period of low production, when excess filter capacity is available.

TABLE 1

Pretreatment Results, 1959–60

Plant	Raw Water	Settled Water	Plant Effluent	Alum Concentration *ppm*	Turbidity Reduction %
	Turbidity—*units*				
Water Works Park	11	7	0.4	9.6	36.3
Springwells	11	6	0.2	9.0	45.5
Northeast	11	5	0.3	9.0	54.5
Springwells Addition	11	0.8	0.1	8.0	92.7

Springwells

The original Springwells plant is not equipped with mechanical rapid-mixing basins or mechanical flocculators. Chlorinated raw water flows from the low-lift pumps through two conduits into the mixing basin, which is 75 ft wide, 335 ft long, and has around-the-end baffles to increase the mixing efficiency. The alum-dosing point is located at the entrance of the mixing basin. There are four settling basins, each 340 ft long, 135 ft wide, with an average depth of 18 ft. At the end of the settling basins, the water flows over the weirs into a collecting channel to the filters. The detention time is 2.2 hr at a 272-mgd flow.

The reduction in turbidity averages 50 per cent. The settled-water turbidity averages 6 units. Efficiency test runs on these basins at different rates showed uneven distribution of flow between the basins. The efficiencies decreased as the rate increased. A study of the sludge depths in the basins also confirmed the unequal distribution of flow. The difficulties in pretreatment at Springwells are attributed to: (1) inadequate flocculation, (2) high conduit velocities between mixing basin and settling basins at higher rates, and (3) uneven distribution of flow through the settling basins.

Northeast

The Northeast treatment plant consists of two separate water treatment plants in parallel. Chlorinated water flows from the low-lift pumps through two separate conduits, through transition chambers, and into four rapid-mix basins, two for each conduit. Each basin is equipped with two variable-speed, stainless-steel, turbine-type mixers. The chemical-dosing points were at the entrance to the transition chambers. From the mixing basins, the water flows through conduits and regulatory vanes into the four flocculating chambers, each with seven channels.

Each channel has four reel-type flocculators whose axes are perpendicular to the water flow. The speed and direction of rotation of these can be varied. There are four settling basins, each 116 ft wide, 415 ft long, and 18.5 ft deep. The detention time is 3.4 hr at 192-mgd flow.

The reduction in turbidity averaged 55 per cent; the settled water had a turbidity of 5 units. These pretreatment results showed little improvement over those of the two older plants that do not have rapid-mix basins and flocculation. A series of laboratory studies was made by experimenting with one plant and using the other as a control. The following was learned:

1. The rapid mixers did not improve results.
2. The flocculators did help build floc.
3. There was even flow through the basins, as indicated by even sludge depths across the basins.
4. Floc was settling in the header before the flocculators.

Laboratory settling tests on samples collected from the various stages of pretreatment showed that:

1. Floc was forming before reaching the mixing basin.
2. The mixing basin acted to break the floc so that it settled slowly.
3. Floc, which settled slowly, was present before the flocculators.
4. Floc from the flocculators settled rapidly, but considerable colloidal material was present.
6. A better floc could be produced with the same alum dose in a jar test.

Improved results were obtained by moving the alum-dosing point to the entrance of the mixing basin.

TABLE 2

Pretreatment Results 1960–61

Plant	Raw Water	Settled Water	Plant Effluent	Alum Concentration *ppm*	Turbidity Reduction %
	Turbidity—*units*				
Water Works Park	20	9	0.3	8.0	55.0
Springwells	20	6	0.1	6.1	70.0
Northeast	20	5	0.1	6.3	75.0
Springwells Addition	20	1.3	0.1	6.1	93.5

Springwells Addition

The Springwells Addition consists of two separate parallel plants extending from the low-lift pumps to beyond the filters. Flows through each plant can be regulated by means of electrically operated, remote-controlled butterfly valves located at the entrance to the mixing chambers. The alum-dosing points are just beyond and are so designed that the alum solution is fed at the center line of each valve. Each plant has a rapid-mix chamber consisting of two successive mixing compartments, each approximately 13 ft square and 20 ft deep. Electrically driven, vertical turbine-type mixers with a three-speed gear reducer are in each compartment.

Each mixing basin supplies ten flocculator chambers, the inlet to which consists of 24-in. manually operated butterfly valves. A concrete baffle is located just beyond the outlet end of these valves to disperse the flow. To prevent short circuiting, each floccu-

lator chamber consists of four successive compartments, each approximately 19 ft wide and 20 ft deep. The first compartment is open and is 21 ft long, with the remaining three compartments slightly longer. Each flocculator assembly consists of eight reel-type paddles mounted on a single longitudinal shaft with the drive at the end of the basin. The first six paddles are identical, with four arms per paddle and four blades per arm. The last two paddles in the fourth compartment have only two arms and two blades per arm. The consulting engineers used this design because their laboratory studies on the raw water indicated that optimum settling would be obtained by quick reduction in flocculation speed. A concrete wall divides successive flocculator compartments and has an access door and a 4×4-ft opening centered on the flocculator shaft. A 6×6-ft steel target baffle is provided at a distance of 1 ft from the outlet end of the openings. The baffle also serves to prevent short circuiting.

The twenty flocculator chambers discharge through a perforated baffle wall into four settling basins, each 484 ft long and 100 ft wide, with an effective water depth of 13–17 ft. The detention time is 3.2 hr at a rate of 180 mgd. The settled water flows over weirs to the settled-water conduits and to the filters.

During the year this plant has been in operation, it has removed 92 per cent of the turbidity and has produced a settled water of 0.8 units turbidity. Basin efficiencies have been approximately 90 per cent or better.

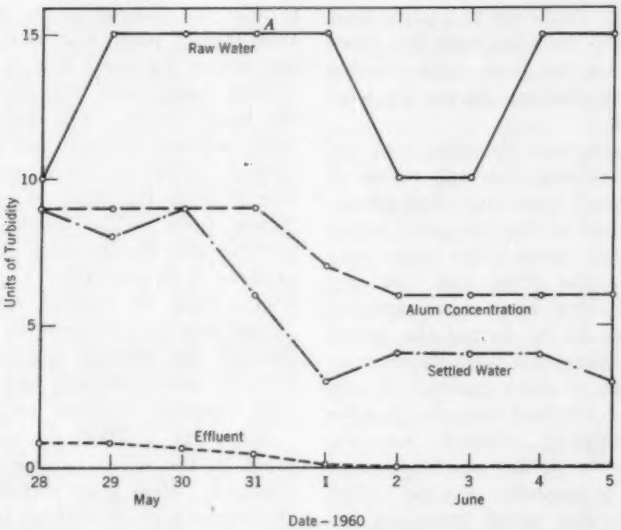

Fig. 1. Effect of Dosing Point on Pretreatment Results at Springwells
Point A on the curve for raw water represents when the new alum diffuser was placed in service. Alum concentration is in parts per million at the values shown on the verticle scale.

Pretreatment Results

For the fiscal year 1959–60, the pretreatment results shown in Table 1 were obtained from the four water treatment plants. It is believed that the greater efficiency of pretreatment at the Springwells Addition is the result of better mixing, the prevention of short circuiting through the flocculation chambers, and the more efficient flowthrough characteristics of the settling basins. Although this plant does remove more turbidity than the other plants, it has not been more efficient in removing plankton during the winter months.

The Springwells Addition was designed for recirculation and re-use of the waste wash water from both plants. With one-half of the new plant acting as a control, waste wash water was pumped to the other half. It was found that filter runs were increased as much as 15 hr during the period of low turbidity and poor flocculation, without loss of water quality. Plankton studies revealed that the number of filter-clogging diatoms was reduced, but the lighter weight plankton increased in numbers. As the turbidity of the raw water increased, the beneficial effect of recirculation of waste wash water decreased somewhat.

As the initial mixing of alum with the raw water appeared to be of the utmost importance, it was decided to try changing the alum dosing points at Springwells and Northeast, and later at Water Works Park. New vertical diffusers were installed across the outlet of the raw-water conduits at the original Springwells. A diffuser consisted of a 3-in.-diameter rubber-lined pipe with 1-in. diameter holes on the downstream side of the pipe, 6 in. center to center. The improvement in pretreatment results were dramatic and the intial mixture of alum with raw water important, as shown by the results (Fig. 1).

The reduction in turbidity through the settling basin increased to 60–75 per cent, and the quality of the effluent from the filters improved. This was also accompanied by a reduction of 33 per cent in the alum dose. No other changes were made.

In an attempt to improve treatment results at Northeast, a temporary alum-dosing point was located at the entrance of the north half of the north mixing basin, with the other half of the basin closed. The south mixing basin was not changed and acted as a control. This presented an opportunity to learn the effect of moving the dosing point. The improvement in pretreatment results were as dramatic as those at Springwells. Compared to results from the control, there was a 14 per cent greater turbidity reduction through the settling basins, a lower turbidity plant effluent, and a 20 per cent reduction in alum usage.

Since Jul. 1, 1960, the alum-dosing point in the south mixing basin was changed. New alum diffusers across the entrance of the mixing basins have been installed at Northeast, with the result that this plant as well as Springwells, is producing better quality plant effluents with less coagulant.

From Jul. 1, 1960, to Apr. 1, 1961, the pretreatment results shown in Table 2 were obtained from the four water treatment plants. These results show greater turbidity reduction through the settling basins, with a 22.5 per cent decrease in alum dosage. The relocation of the alum-dosing point was the only change made at the Springwells and Northeast plants. It is planned to study and make improvements at Water Works Park in 1962.

Comparison of Analytical Procedures for Boron

Raymond J. Lishka

A contribution to the Journal by Raymond J. Lishka, Chemist, Analytical Reference Service, Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

THE determination of boron in waters, industrial wastes, and sewage effluents is particularly important to agriculture. Interest in the presence of traces of boron in irrigation water has increased in recent years. Boron in small quantities is one of the essential nutrients for many types of plant life, but in high concentration it often produces injurious effects. Concentrations in excess of 2.0 mg/l in irrigation water are deleterious to many plants, and there is evidence that some plants are adversely affected by as little as 1.0 mg/l. Recommended boron tolerances for some crops are as low as 0.33 mg/l. Obtaining and using boron data for these purposes require a method that is very sensitive, easy to perform, not susceptible to interferences common in water, and not demanding an excessive volume of sample.

Dianthrimide Reaction

A study has been made of available methods in an effort to select the one that most nearly meets these requirements. From an investigation [1] of twenty compounds found to be colorimetric reagents for boron when reacted in concentrated sulfuric acid, 1,1′-dianthrimide was recommended as the reagent of choice. This reagent is soluble in concentrated sulfuric acid but precipitates readily in the presence of traces of moisture. Its reaction with boron produces a blue color which can be measured photometrically and compared with standards. Unfortunately, the reaction is carried on in an oven at 90°C, and requires close temperature control and uniformity of temperature throughout the oven.[2] Maximum color development is obtained after the reaction has proceeded for 3 hr at 90°C. At room temperature the reaction progresses very slowly, if at all. Increased temperature increases the reaction rate, but the timing for maximum color development becomes critical and the sensitivity variable. Prolonged heating or temperatures higher than 90°C volatilize an excessive amount of boron and decrease the sensitivity of the test. Both nitrate and alkalinity cause off-colors of the boron-dianthrimide complex, but those interferences may be eliminated by evaporating water from the sample in the presence of sulfuric acid. This evaporation, however, may be another source of error, because some boron may be volatilized during evaporation.

Carmine Colorimetric Method

The carmine colorimetric method [3] does not require temperature control and is claimed to be capable of accurate results reproducible within ±0.4 μg

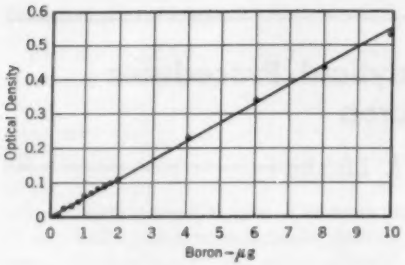

Fig. 1. Standard Boron Curve Obtained by the Carmine Colorimetric Procedure

This procedure does not require temperature control.

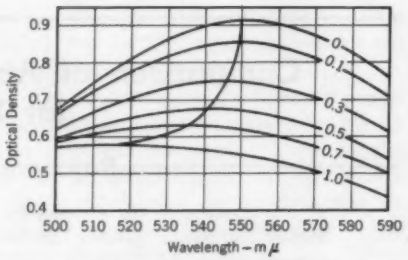

Fig. 2. Shift in Peak Absorbance With Variation of Boron Concentration in Victoria Violet Procedure

Values on the curves are for milligrams of boron. The curve extending upward through the other curves connects the points of maximum absorbance for the various concentrations of boron.

B. In this investigation it was found that the concentration of the carmine solution as specified produced too much color for spectrophotometric reading. The solution was diluted 1:10 with concentrated H_2SO_4, and a linear plot was obtained in the range 0–10 μg B (Fig. 1). As a check on recovery, nine 100-ml aliquots of river water were treated as follows: three were run as controls, three contained 0.02 mg/l B added and three contained 0.05 mg/l B added. The analysis showed 0.036 mg/l B in the river water controls and 0.028 mg/l and 0.052 mg/l added in the other sets. The analytical results are shown in Table 1.

The shortcomings of the procedure are:

1. When the boron concentration is less than 1 mg/l, a time-consuming evaporation step is required
2. Without evaporation, the minimum detectable concentration is 0.2 mg/l B
3. There is a long waiting period for the acid-water solution to cool, and another 45-min wait for maximum color development
4. Incomplete mixing of the solutions will cause bubbles when transferred to the optical cell, constituting a serious source of error
5. The reaction takes place in concentrated H_2SO_4, which is unpleasant to handle, particularly when pouring into spectrophotometer cells.

TABLE 1

Analytical Results With Carmine Colorimetric Method

Water Used	Results of Analysis—mg/l B					Recovery %
	Sample 1	Sample 2	Sample 3	Average	Difference	
River water control	0.045	0.028	0.035	0.036		
River water +0.02 mg/l B	0.070	0.060	0.061	0.064	0.028	140
River water +0.05 mg/l B	0.083	0.090	0.090	0.088	0.052	104

Victoria Violet

In hope of finding a procedure that did not present the above shortcomings, the colorimetric determination of boron in aqueous solutions utilizing the colored complex formed between boric acid and Victoria Violet was investigated by Reynolds.[4] He reported that the presence of boric acid caused a decrease in the absorbance peak of Victoria Violet in the pH range 7.7–10.0, but the difference was greatest in the pH range 8.5–9.0. The actual value of the absorbance difference was found to be critically dependent on pH, which should not vary by more than 0.1 pH unit. Stability was assured by the use of a bicarbonate-carbonate buffer solution of pH 8.75. Boric acid not only decreased the absorption maximum, but also shifted the absorption peak. For this reason the recommended procedure specifies scanning from 800 mμ to 450 mμ and determining the peak for each concentration of boron. No great problem was encountered with a double-beam recording spectrophotometer like the one * used by the author, but instrument readings become a long, tedious task when a less elaborate instrument must be used. Reynolds also employed a multiplier phototube which gave a reproducibility of about 2 per cent when samples larger than 200 μg B were used. It was claimed that the reaction followed Beer's law from 1 to 22 mg/l.

In the author's investigation the above was verified, but it was found that the specified dye concentration had too high an absorbance to read on the spectrophotometer used.† The dye concentration was accordingly reduced by 80 per cent. It was found that at any particular wavelength the plot of differential readings from the blank was linear from 0 to 0.3 mg/l B, but above this point the linearity ceased. The scanning curves in Fig. 2 illustrate the shift in peak absorbance from 0 to 1.0 mg/l B.

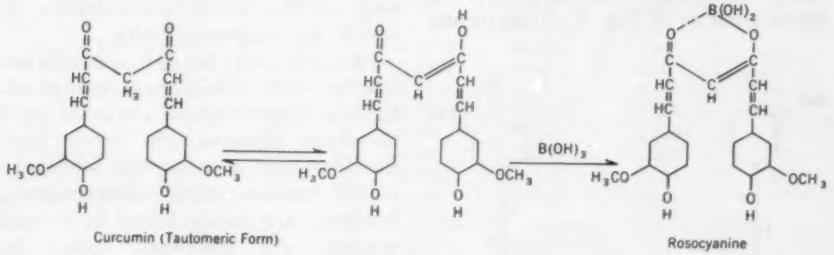

Fig. 3. Curcumin-Rosocyanine Reaction

This is one interpretation of the reaction.

Cations such as ferric ion, aluminum ion, and chromium ion precipitate as do the hydrous oxides at the pH at which absorbance measurements are made. Therefore, a separation of these substances is required before a boron analysis is attempted. Strong oxidizing agents such as permanganate, ceric ion, and dichromate must not be present, because of their effect on the

* Model DK-1, Beckman Instruments, Fullerton, Calif.

† Model B, Beckman Instruments, Fullerton, Calif.

dye itself. To achieve the desired sensitivity, a concentration step would have to be incorporated into the procedure, which would entail pH adjustment.

Curcumin Procedure

The curcumin procedure[3] involves the acidification of a 1-ml sample of water containing boron, followed by evaporation to dryness in the presence of curcumin. A red product called rosocyanine is formed, which is taken up in a suitable solvent and compared with standards. According to Silverman and Trego,[5] the reaction is believed to be as illustrated in Fig. 3.

Spicer and Strickland,[6] however, state that rosocyanine is a complex monovalent cation containing two curcumin molecules coordinated to a boron atom as in Fig. 4. This means

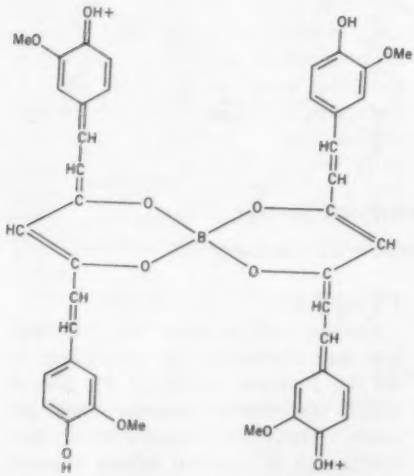

Fig. 4. Curcumin-Rosocyanine Reaction—Another View

If this interpretation is correct, more curcumin is required.

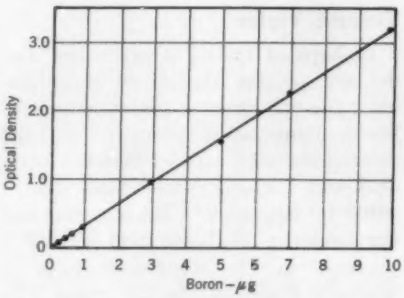

Fig. 5. Standard Boron Curve Obtained by the Curcumin Method

Previous work specified that the reaction was linear only up to 1.0 mg B.

that to react with a given amount of boron, more curcumin is required. Sufficient reagent is provided by the procedure to maintain an excess as long as the boron concentration is within the suggested limits.

Ions commonly found in water do not interfere with this method, except nitrates at concentrations above 20 mg/l as nitrate nitrogen, and except high fluorides that decrease the sensitivity of the reaction; these concentrations, however, are rarely found in ground waters. All glassware should be cleaned with hot hydrochloric acid, followed by acetone and distilled water. The specified evaporation temperature of 55°±2°C is quite critical but is easily controlled with a water bath as specified. Color will be lost if the temperature becomes too high. All colorimetric readings should be made within 1 hr after solution of the red product in alcohol, as the rosocyanine slowly hydrolyzes back to curcumin. It has been observed in the author's investigation, however, that leaving the samples in the water bath for as much as 1 hr after they become dry has no

measurable effect on the colored product. On the other hand, a variation in time required to reach dryness will have a considerable effect on the end product. If little or no sodium chloride, sodium oxalate, or oxalic acid precipitated during the initial stages of the evaporation, the time required to take the sample to dryness will be increased and the resulting color will be more intense. If salts precipitate readily, a large area of wetted surface will be available and the evaporation will be rapid. The method specifies a range of standards from 0.1 to 1.0 μg B, but the reaction was found to be linear up to 10 μg (Fig. 5), which is sufficient for any surface waters so far encountered, thereby obviating any need for either concentration procedure or dilution step.

The recovery of an added amount of boron from several river waters and brackish surface waters was investigated and found to be satisfactory. Results are shown in Table 2.

TABLE 2

Analytical Results With Curcumin Procedure

Source of Sample	Boron Content mg/l	Boron Added mg/l	Total Boron mg/l	Total Boron Recovered mg/l	Recovery %
Little Miami River	0.11	0.25	0.36	0.42	124
Little Miami River	0.21	0.25	0.46	0.50	116
Little Miami River	0.10	0.25	0.35	0.36	104
Ohio River	0.075	0.20	0.275	0.275	100
No. 2 brine	2.375	0.375	2.750	2.700	87
No. 4 brine	1.575	0.500	2.075	2.060	97
No. 9 brine	0.980	0.375	1.355	1.280	80
No. 16 brine	0.225	0.500	0.725	0.640	83

Summary

An investigation has been made to find a rapid, simple, and sensitive procedure for the determination of boron in various types of surface waters. Many compounds were found to be colorimetric reagents for boron, and four were selected for further study.

1. The reaction with 1,1′-dianthrimide progresses slowly, requiring 3 hr for maximum color development. Temperature must be closely controlled at 90°C.

2. The carmine colorimetric method does not require temperature control, but is nearly as time consuming as the 1,1′-dianthrimide procedure. Both reagents require concentrated sulfuric acid as a solvent.

3. The Victoria Violet reaction takes place in aqueous solution without close temperature control. Different concentrations of boron produce an absorption peak at varying wavelengths, which makes the use of a double-beam recording spectrophotometer nearly mandatory.

4. The procedure with curcumin uses a minimal amount of sample and forms an end product that is soluble in alcohol. A water bath controlled at 55°C is the only equipment re-

quired. The method produces satisfactory results in various types of surface waters.

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Personal Reminiscences of George Warren Fuller

James C. Harding

An address presented on Jun. 7, 1961, at the Fuller Award Breakfast at the Annual Conference, Detroit, Mich., by James C. Harding, Comr. of Public Works, Westchester County, White Plains, N.Y.

I AM going to give you some of my recollections of George Fuller. They are somewhat censored. I have been warned by some of his contemporaries here this morning not to say anything that will detract from his stature. I certainly have no intention of so doing. On the other hand, I can't paint him as a saint, because that is something he definitely was not. These remarks are based on my memories of the Fuller of a long time ago, between 1910 and 1927. Perhaps they will serve to give you an insight into the personal and human side of this remarkable man.

My father went to work for the firm of Hering and Fuller in 1906 and stayed with Fuller in various capacities for most of the next 20 years. I first met Fuller when I was about 12 years old, when he was a somewhat infrequent visitor at our home. I started working for Fuller and McClintock in 1918 and was employed by them directly or indirectly until 1927, when I went into private practice with my father. From then until the time of Fuller's death in 1934, I had occasional contacts with him and, as a matter of fact, had it not been for a few jobs he generously threw my way, I would not have been able to remain in business.

I suppose that the first thing I should mention is what George Fuller looked like. He was a big man, somewhat over 6 ft tall and weighing about 285 lb, all of which was not bone and muscle. He was distinguished looking, well groomed, and carefully dressed.

My first experience in research work was occasioned by Fuller's bulkiness. We were in Philadelphia where he was to appear as a witness in several important cases. As a result of nicking himself with a razor, he ruined his last collar. He said, "Jimmy, run out and get me a couple of collars, size 18." This appeared easy, but after visiting five haberdashery shops on the double and being told scornfully that they did not come larger than 17½, I had to compromise on that size. With my assistance on the overstressed collar button, we finally managed to squeeze him into the smaller size, but his normally florid complexion was somewhat pinker than usual during the time he was on the stand.

Not only was Fuller a big man physically, but he was a big man in every other way. In my experience, I have never met another man with equal energy and drive both in work and play. He was absolutely tireless. He could put in 10 or 12 hours a day regularly at his work, play hard at night, and yet feel fine when he arrived at the office in the morning.

He was frequently if not generally on the road, either in this country or abroad, but far from tiring him, his trips seemed to refresh him.

Fuller had a pleasant personality and an almost overwhelming one. He was genial, courteous, and very impressive. He could turn on the charm whenever he wished, and vary its type with the person or audience. He was a good story teller and a brilliant conversationalist. He was normally dignified yet warm, but he could be very much otherwise when he felt so inclined.

His kindness is exemplified by his treatment of a German governess of his children who, after World War I, had a very hard time of it in Germany. Fuller took care of her for a number of years, seeing that she had coal, food, lodgings, and the other essentials of life. There were many others whom he assisted financially in an unostentatious manner. On the other hand, he could be ruthless; he had little regard for public opinion except when necessary to further some cause in which he was interested.

George Fuller was not an orator, but he was a good speaker and knew how to play on his audience, be it at a technical meeting or a public hearing in some small mill town. He could always see the other man's viewpoint without agreeing with it, and adjust himself accordingly. In a conference to reconcile conflicting views, his diplomacy was unequaled. On the stand before a court or commission, he was as good a witness as I have ever heard, whether he was well prepared or not. If he did not know the answer, he had the ability to confuse the opposing attorney so that his testimony remained unimpugned.

Ernest Whitlock tells a story about an occasion when Fuller was testifying as an expert. The cross examination was pretty tough, and Fuller was having a rather difficult time of it. All of a sudden he gave a very convincing imitation of a man stricken with apoplexy. The judge adjourned court and attendants rushed to Fuller's aid. Later on he admitted that the trouble was that he had swallowed his chew of tobacco. Of course, chewing tobacco in court was not an accepted practice, even in those days, but Fuller was never known for his orthodoxy. Whether or not he did this deliberately is a matter of conjecture. If so, it was entirely successful, because the opposing attorney never did recover his line of questioning.

Fuller was a perfectionist. Once given a job by a client, he never tried to economize on his engineering costs. If he did not like the plans prepared by the office at substantial expense, he would order them discarded and new ones made. Many consultants spend most of their own time getting business, handling public relations, and performing executive functions. Fuller did all this but was also thoroughly expert on all phases of the work done by his office, and gave enough time to the various jobs, profitable or not, to make sure that his client's best interests were well served.

He was calm and unruffled. It took quite a bit to get him really steamed up. When this did happen, it was best to get as far away from him as possible. I think the only occasion that I ever saw him really embarrassed and upset was one time when we made an inspection of a new sewage treatment plant that we had built for the city of New Rochelle. Present at this

inspection was the mayor, a very dapper, well dressed individual. On this particular occasion, he was unusually so, because after making the inspection he was to entertain Paderewski at dinner and then preside at his concert. At the plant there were fine screens from which the screenings were removed by a bucket elevator and dumped into large hoppers over each of the two sewage ejectors. When the ejectors were full, the operator would pull one lever to close the top valve, normally open, and open the bottom valve, normally closed. He would then pull another lever which would throw compressed air, under 100 psi, into the ejector so that the screenings, which as you can imagine were messy and malodorous in character and soupy in consistency, would be blown out of the ejector.

His honor was standing at the point where the screenings dropped into the hopper, with Fuller off to one side explaining just how things worked. Unfortunately, the operator chose that moment to throw the air into the wrong ejector. There was a great roar, and those who knew what was going to happen ducked. Of course, the mayor did not know, and he was plastered from the waist up with a layer of filth 2 in. thick. After his face was sufficiently wiped off—with a pair of overalls, incidentally—so that he dared to open his mouth to speak, he called the operator a number of foul names finishing up with "Democrat," told him he was fired, and then turned to the highly embarrassed Fuller saying these words, "Great engineer, huh —Fuller and McClintock—Fuller—!"

Fuller had remarkable ability when it came to making money. He could pretty well size up what a municipality was prepared to spend for a particular project in the way of engineering fees and then talk them into spending a substantially larger sum. His ability to spend money was even greater, and it seemed that no matter how many profitable jobs we had in the office, the bank account was always in need of replenishing. I remember a time when I was working on a project in Waterbury, Conn. Included among my various important duties such as cutting brush, driving stakes, and rushing the beer pail for the older and wiser members of the survey party, was that of timekeeper and paymaster. We were put up at a very good hotel and were all right for food, lodgings, cigarettes, and anything else that we could charge; however, there were no weekly paychecks and some of the boys were pretty hard pressed for cash. They held a meeting and decided that I should go to New York and tell the boss that he really had to get some money on the line. With considerable trepidation, I approached him on this matter and informed him that one man, a particular friend of his, had told me that unless he got at least $100 the following day, he would have to go to jail. Fuller could not have been less impressed. He said, "You go back to Waterbury and tell that damn Major Reynolds that he has spent most of his life in front of bars and it would be a good thing for him now to spend a little time behind them!"

Fuller was a Republican up until the time of the depression, but became so thoroughly disgusted with another great engineer, Herbert Hoover, that he turned Democrat. Early in the depression he had come back from England with the idea that we should follow the British example and insti-

tute a large program of subsidized public works construction. His recommendation was ignored by Hoover and subsequently put into effect under Roosevelt.

He had other interests besides engineering. He was a silent partner in a Wall Street brokerage firm. He owned a ranch in Idaho. He was an angel for Broadway shows. He was active in real estate. I do not believe he was particularly successful in any of these extracurricular ventures.

I am not going into Fuller's activities in AWWA. You can read about these elsewhere. It should be remembered, however, that in the early 1920's, although we had capable secretaries, none of them could provide the leadership and dynamism we subsequently received from Harry Jordan. For several years this service was provided by Fuller. He had the man who was secretary at that time move his office to 170 Broadway, where Fuller had his own office, so that Fuller might more closely supervise association activities. He worked diligently to expand the membership. He had everyone in his office, outside of the stenographers, become members and, I believe, paid the dues for most of them. I know he did mine. He was largely instrumental in establishing what later became the Water Works Practice Committee.

One of Fuller's principal outside cultural interests was the Pleiades Club, an organization which met about once a month in the old Brevoort Hotel to partake of a rather sumptious meal and enjoy entertainment. The rules were that the chairman for the evening had to provide a first-class show but could not pay for it. Fuller ran "engineer's night" once a year, and by pulling all the strings he could, managed to get theatrical and radio stars of the first order to sing, dance, or otherwise entertain. It was a rather erudite group which I joined because Fuller told me to. That he also paid my dues goes without saying.

It is said of many men that their principal interests were wine, women, and song, and was said of Fuller that his principal interests were wine, women, and real estate. I don't know about the real estate, but he certainly liked the wine, or rather the stronger alcoholic beverages, and the women. Furthermore, he had a great love of good food.

I know about the liquor because, being the most expendable and least valuable member of the organization, it was part of my duties to pick up and deliver liquor, and carry bottles to conventions and meetings. During the early days of Prohibition, Fuller, like most people, would drink practically anything, even the very foul-tasting beverage that my father distilled every other Sunday morning in the cellar of our house. He would also drink applejack, which we used to bring down in sizeable quantities from Newburgh, where we had a job. I believe, however, that his favorite was Scotch. When the bootleggers began to get better organized, this seemed to be his principal social beverage. At that time, a bottle of alleged good Scotch cost $18, although the price subsequently dropped.

By these remarks I do not mean to infer that Fuller was in any sense a problem drinker. Liquor did not seem to bother him. He did not always stay strictly sober, but if he had something to do that he considered important, he could snap right out of it. He addressed many technical meetings ably and in a dignified manner with enough

liquor in that huge frame of his to put at least three ordinary men to sleep.

His appetite for food was as great as that for liquor; he could consume it in astounding quantities if it happened to be something that he liked. A minute steak to him would be like a slice of bacon to the ordinary man. I remember that when he came to our house my mother would start preparations at least a week ahead of time. She would order the biggest steak obtainable, and then Fuller and my father, who was no soft touch from the eating standpoint, evidenced by his 250 lb, would go to work on it. We kids were not allowed to sit down with them, and between the two they generally saw to it that nothing edible went back to the kitchen. He was decidedly not a glutton. It just took a lot of Btu's to generate that much energy.

I have said that Fuller was a great lover of liquor and of food. I do not know whether he was a "great lover" in the normally accepted sense of the phrase, but he was certainly very fond of the opposite sex. He was married four times.

The story is told that at his fourth wedding he asked his bride, "Eleanor, what time shall we set for the wedding?" Her reply, "I don't care; what time do you usually set for your weddings, George?"

Fuller died at 65. If it can be said of anyone that they lived a full life, it certainly can be so said of George Warren Fuller. His outstanding ability and achievements as an engineer, his devotion to the advancement of sanitary engineering and its various professional organizations, particularly AWWA, his unequalled physical and mental energy, and the fact that in every sense of the word, he was a man, should make all of us gathered here this morning proud that we are the recipients of the awards given annually in his memory.

Notes and Comment

Water Resources of Guam

Chet Eyer

Water Div. Mgr., Public Utility Agency, Agana, Guam.

The island of Guam is the most westerly territory of the United States and is the southernmost and largest of a chain of seventeen volcanic islands known as the Marianas Islands. Shaped like a kidney bean, Guam is 32 mi long and 4–8 mi wide, covering an area of 225 sq mi. The civilian population (39,333) obtains water supplies from several sources.

The island is unique in that the central and northern portions are broad, terraced limestone plateaus with high cliffs to the ocean, and the only water source is from the fresh-water lens formed by the rainfall penetrating and filtering through the porous limestone formation. More than 85 per cent of the rainfall occurs in the northern and central parts of the island. There is very little runoff, as there are no rivers or streams in this portion of the island.

The average annual rainfall is 86.7 in., making ground water available from wells and springs. The springs in the northern part of the island discharge just a few feet above the high-tide level and at times mix with the fresh water and cause the water to become brackish. There are no springs being used in this area for the water supply of the civilian population.

At the present time, the only withdrawal of ground water by the Guam Public Utility Agency for civilian use is to serve the village of Yigo (population 953) with 10.2 mil gal/year. The village of Dededo (population 2,323) and the surrounding area are served water produced by the US Air Force from ground water installations. Approximately 42.8 mil gal was used in 1958 and 47.3 mil gal in 1959. The total amount of ground water withdrawn by military installations is classified information for this area.

The terrain in southern Guam is mostly hilly, and the underlying rock has moderate to low permeability. Therefore, a large part of the rainfall is discharged quickly by surface runoff. The streams respond rapidly to rainfall and subside almost immediately after the rain stops. Storm runoff rapidly flowing over the highly weathered volcanic rock carries considerable amounts of silt.

The streams in Guam are short; the valleys, especially inland, are narrow and steep sided. As the shore is neared, the gradient becomes more gentle, and the valleys widen and terminate in small bays. Because the gradients near the shore are gentle, tide water migrates upstream during high tide. The majority of the streams originate in the weathered, upland volcanic rock, which discharges sufficient water through seepage and small springs to maintain dry-weather flow for the perennial streams.

The Public Utility Agency of Guam has developed rivers and springs to serve the civilian population with safe,

TABLE 1

Sources of Supply Serving Civilian Population of Guam

Location of Water Source	Population*	Water Produced in 1958 *mil gal*
Umatac	651	8.3
Merizo	1,333	20.3
Inarajan	1,716	21.8
Asan	1,493	60.1

* As of Jun. 30, 1959.

clean, potable water. The location and size of these sources of supply are shown in Table 1.

In 1958, the Ylig River plant served the villages of Yona and Talofofo and the Camp Witek and Camp Dealy areas with 133.7 mil gal. The other villages were served 960.3 mil gal purchased from the US Navy's Fena River system. These values and those in Table 1 pertain to the civilian population only, and do not include the military.

The civilian per capita consumption has increased in the past few years. Water plants have been extended to make water available to populous areas. Houses are being modernized, and new washing machines and appliances have been the greatest cause for the per capita increase in water consumption.

Sewage disposal is one problem that should be given a great deal of consideration very soon. Agana Spring, one of the largest springs, is not being used as a result of pollution due to seepage from septic tanks in a nearby village. Sewers should be installed and the sewage carried to the ocean for disposal in order to preserve the ground water supply.

The future demands of the civilian population will not be too great a problem, even with the increased per capita consumption. The mains that were temporarily installed by the military are being replaced with permanent constructions; and with each project completed, the water that was produced and lost through leaks can be utilized to serve more people without increased production. The Public Utility Agency has made a 5-year plan for developments and extensions. Within the next 3 years, most of the old mains will have been replaced and the leakage controlled.

The probability that any large amount of water will be available for industrial use in the foreseeable future is small; the same is true for any large amount for agricultural development because of the limited amount of good soil and area available. As for the climate, even during the dry season, the records show that there is, on the average, more than 1 in. of rainfall per month. Because of the rainfall and because the humidity is 70–90 per cent even during the dry season, a great deal of water is not required.

The future demands for water will require large capital outlays to build storage and filtration plants on the existing rivers to preserve the water that is now running back to the ocean. But the greatest problem at the present time is the lack of transmission and distribution mains to all areas, which are fed from only one source. Cross connections to maintain service at all times are also lacking. Plans are being made to install permanent lines of adequate capacity to make water available from more than one installation.

Customer Meters

AWWA Distribution Manual

A training course in water distribution has been prepared under the supervision of AWWA Committee 4620 M—Education. This is the last of six installments (see April, p. 458; June, p. 790; July, p. 907; August, p. 1174; October, p. 1313). The manual will be issued as a separate volume (date and price to be announced).

TWO basic types of water meters are used for customer service—positive-displacement meters and current meters. The latter are often called velocity, turbine, or inferential meters. Two other important types of meters, which in reality are adaptations or combinations of the two basic types, are the proportional meter and the compound meter.*

Positive-Displacement Meters

The positive-displacement meter derives its name from the manner in which it measures the water. It utilizes a measuring chamber, usually cylindrical in shape, having a given volumetric capacity. This chamber contains a piston or disc which goes through a certain cycle of motion corresponding to a single filling and emptying of the chamber and transmits its movement to a register. The different ways in which the piston moves in various designs have caused a subdivision of positive-displacement meters into nutating-, rotating-, oscillating-, and reciprocating-disc (or -piston) meters.

The nutating-disc meter has several advantageous features among which are simplicity of construction, continuous sensitivity and accuracy, low loss of head, and low maintenance cost. The oscillating-piston meter also has certain very desirable characteristics and is therefore preferred by some.

Disc meters range in size from § in. to 6 in., are accurate at all rates of flow within normal test flow limits, and, in sizes up to 2 in., are remarkably sensitive at low rates of flow. In sizes greater than 2 in., the sensitivity at the lower rates of flow decreases to such an extent that it is generally advisable to use another type of meter. Furthermore, large disc meters are more troublesome from the point of view of maintenance.

* For a complete description of water meters, their selection, installation, testing, and maintenance, reference should be made to AWWA Manual M6—Water Meters. Am. Wtr. Wks. Assn., New York (1959).

One of the advantages of positive-displacement meters is that the accuracy of registration is not apt to be affected by the setting of the meter or the character of the water. Fine sediment collecting on the disc or in the chamber may cause the meter to overregister, but only to a limited extent. Foreign matter in large quantities will either stop the meter or cause its accuracy to decrease because of friction. The fact that there is a limit to the overregistration of positive-displacement meters is one of the reasons why their use is sanctioned.

Current Meters

The current, or velocity, meter also derives its name from the method of measuring the water. The measuring device is a bladed wheel which the incoming water strikes. The impact results in rotation of the wheel, and from the number of rotations the quantity of water that has passed through the blades may be computed. The volume of water recorded on the register of the meter is directly proportional to the number of revolutions made by the wheel. An intrinsic fault of the current meter is that it is not accurate at low rates of flow. There is considerable slippage at low rates, and the water must be moving at a sufficient velocity before the wheel will start to rotate.

Current meters are used only where large drafts of water are expected. They should never be used where there is any possibility of low rates of flow. In many water systems it will be found that there is only a limited number of installations favorable to this particular type of meter. Current meters may be used to advantage on sprinkler carts that draw water from hydrants at high rates of flow, on hydraulic elevators and cranes, in jetting down piles, on water towers and, in short, on any installation demanding periodic or continuous heavy drafts of water with no probability of low rates of flow. They are absolutely unsuitable for dwellings, schools, office buildings, hotels, or similar types of service conditions. where the flow rates vary from zero to high rates.

Current meters also tend to overregister when the blades of the wheel become partially clogged or coated with sediment or foreign material. This condition causes a decrease in the cross-sectional area of the openings between the blades, and, as a result, for any given rate of flow the water must of necessity pass through these openings at a higher velocity, thus resulting in overregistration. The condition may be kept under some control by periodic inspection and test, however.

Proportional Meters

The proportional meter derives its name from the fact that only a portion of the total flow through the meter passes through a bypass measuring

chamber, which is the actual measuring device. This bypass is so adjusted that its register indicates the total flow through the meter as a whole. The bypass meter may be of either the positive-displacement or current type. Different methods of bypassing of the water may be utilized, such as insertion of an orifice in the main throat, use of a diverging tube, or application of the Venturi principle.

The proportional meter is capable of measuring large volumes of water with comparatively low loss of head. The proportional meter is rarely used as a service meter but is used in compound to form the well-known fire line meters described under "compound meters," below.

Compound Meters

General-Service Compound Meters

The general-service compound meter is usually composed of a current meter, a positive-displacement meter, and a suitable automatic valve arrangement which causes the current meter to operate during the higher rates of flow and the displacement meter during smaller rates of flow. The compound meter combines the merits and characteristics of both of the meters of which it is composed, and its operation should offer no particular difficulty to anyone familiar with these characteristics. It has a rather wide working range and is accurate at all rates of flow within its capacity. The so-called "changeover," which occurs when the rate of flow is at the point where the main valve is just off its seat, is often characterized by a small drop in accuracy of registration. This drop occurs because the operation of the valve allows water to pass through it and thus through the current meter, at rates too small for efficient operation of the wheel. The range of flows in which this occurs in the better models of meters is rather limited, and the slight drop is of no serious consequence, especially if the preponderance of the flow does not occur at the changeover rate.

Compound meters are used on services having a demand beyond the range of disc meters in the sizes normally used and where there is a possibility of low rates of flow. At low rates, of course, the positive-displacement section of the meter takes over. General-service compound meters are also characterized by a fairly high loss of head, which is one of the reasons why they are not used on fire lines.

Fire Line Compound Meters

The popular designs of fire line compound meters utilize a positive-displacement meter to measure accurately at the low rates of flow which frequently occur in fire lines. As the volume of flow increases to a substantial amount, the resulting loss of head causes a main-line valve to open

automatically, thus permitting an unrestricted high rate of flow at a very low loss of head. The proportional-meter principle is utilized to measure at the high rates of flow, but the proportional bypass meter may be either of the positive-displacement type or of the current type.

Fire line meters were designed to meet the requirements of the NBFU for a meter with a low head loss and an unresricted flow, as well as to satisfy the demands of the water supply profession for accuracy and sensitivity at all rates of flow. A low loss of head is achieved by use of the proportional method of measurement.

As the name implies, fire line meters are designed strictly for fire line use. There are unusual circumstances, however, in which both high and low flows occur and it is important that head losses be kept small; in such cases the use of these meters may warrant consideration.

Characteristic Curves

Two characteristic curves may be constructed from data obtained by testing a water meter, an accuracy curve and a loss-of-head curve (Fig. 7.1). Some knowledge of these two curves is essential if one is to understand thoroughly the performance that may be expected of water meters. The overall accuracy curve is especially important, as stress is being laid today on the variations in accuracy of meters over the range of their delivery. It should be observed that rates of flow are given in gallons per minute. All meter test results should be given in gallons per minute, except extremely small rates, which may advisably be expressed in gallons per day. Orifices are widely used to produce various flow rates. Although their use is quite acceptable, final recorded results should not be expressed in terms of orifices, because it disregards pressure. The fact that a meter records with an accuracy of 100 per cent with an orifice of $\frac{1}{4}$ in. is quite meaningless, because the flow through such an orifice varies considerably with the head or pressure on the orifice.

Accuracy Curves

Both AWWA and NEWWA have adopted certain normal test flow limits applicable to the various sizes and types of meters. For example, the flow limits for a $\frac{5}{8}$-in. meter are 1 gpm and 20 gpm. Similarly, minimum test flow rates have been established for each size of meter. These flow rate limits have become accepted as representing capacity ranges of meters, and most characteristic curves are plotted between the limits of zero and the maximum flow rate established by the two associations.

Normal variations. Figure 7.1 shows a typical accuracy curve of test results for a $\frac{5}{8}$-in. meter between the limits of 0 and 35 gpm. The curve

indicates that the variation in accuracy of registration is a function of the rate of flow. In other words, there is a variation in accuracy over the range of delivery of the meter, a difference of about 1.5 per cent between the maximum normal test flow limit of 35 gpm and the peak of the curve, which occurs at approximately 3 gpm. It is possible to shift the entire curve up or down by changing the gears of the meter. The curve as plotted is the result of placing change gears on the meter which produced an accuracy of about 98.5 per cent at 35 gpm, although the meter could easily be regeared to register 99 per cent at this rate, in which case the curve would be shifted upward, and the peak, which would still occur at 3 gpm, would be found to be at 101 per cent.

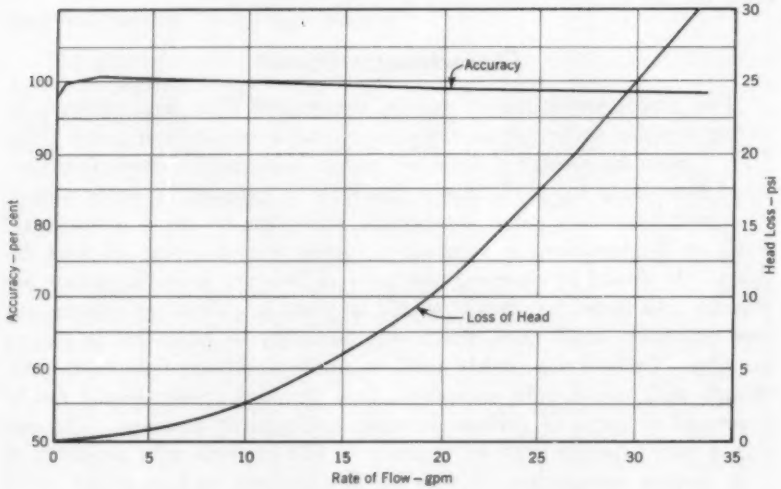

Fig. 7.1. Typical Accuracy and Head Loss Curves, ¾-in. Meter

Current meters have a characteristic accuracy curve similar to that of displacement meters, although in most cases the variation is more pronounced. Compound meters have a characteristic accuracy curve which is a combination of the curves of the current and displacement meters of which they are composed. There is a depression in this curve at the so-called "changeover" point. The drop in accuracy is caused by the inability of the current meter to record accurately the small rates of flow which pass through the main valve as it moves off its seat.

In certain states the allowable variation in registration accuracy is limited by law. A few of these regulations are shown in Table 7.1.

Extreme accuracy of registration at high rates of flow is not nearly so important as at low rates. This is because the greatest proportion of water served, especially through the average ⅝-in. meter, passes through the meter at comparatively low rates of flow. It appears to be true that a ⅝-in. meter that is calibrated to record with an accuracy of 95 per cent at 15 gpm but will also measure 95 per cent of the flow at 0.5 gpm is more likely to show a higher overall registration on an average service than a meter which records 100 per cent of the flow at 15 gpm and only 50 per cent at 0.5 gpm. Nevertheless, it is important to establish limits of accuracy within the range of normal test flow rates. Because there is a variation in accuracy over the delivery range of the meter, absolutely perfect measurement at all flows is impossible. The best that can be done is to calibrate the meter so that it records reasonably close to maximum efficiency with both positive and negative errors which tend to cancel out.

TABLE 7.1

State Limits on Variation in Meter Regulation Accuracy *

State	Allowable Variation *per cent*
Connecticut	±2
Kentucky	±2
Maryland	±1.5
New Jersey	±3
New York	+1, −2
Pennsylvania	±4
Washington	±2
Wisconsin	±2
Oregon	+2, −6

* Displacement meters within normal test limits.

Naturally, under actual service conditions the quantity of water flowing at different rates and the accuracy of measurement at those rates are determining factors.

Accuracy "buildup." In many waters there occurs what is generally termed a "buildup" of registration accuracy. Deposition of sediment or other material on the interior of the measuring chamber and on the piston or disc results in a slight decrease in the volume of the chamber and a reduction of clearance between the moving disc or piston and the chamber walls, thus increasing the accuracy of registration. Continued buildup, however, causes friction, and registration then decreases.

Head Loss Curves

Meter head loss is the water pressure lost in overcoming friction through the meter. Loss of head may be expressed in feet of water or other similar terms, but in dealing with water meters, where elevations

do not enter into the matter, it is clearer to express head loss in terms of pounds per square inch.

Variations in head loss. Loss of head in a water meter varies according to the rate of flow through the meter. The resulting characteristic curve is, however, quite different in shape from the accuracy curve, which also varies as the flow rate changes. A typical curve for an ordinary ⅝-in. meter is shown in Fig. 7.1.

Measurement of head loss. Several kinds of manometers and gages may be used to determine the loss of head at various flows, but pressure gages are simplest to use. Generally, meter tests require the use of gages with large, accurately calibrated scales, which can be read with a close degree of precision. In obtaining the data for the head loss curve, the meter may be placed in the test bench and the gages connected in such a way that they measure the pressure as the water enters the meter and as it leaves the meter.

If there is no flow through the meter the inlet and outlet gages will give the same reading. If the outlet valve of the test bench is opened, permitting a flow of water through the meter, both gages will indicate lower pressures, but the gage at the outlet side of the meter shows less pressure than the inlet gage. The difference between the readings of the two gages is the loss of head in the meter at that particular rate of flow. To plot the head loss curve it is necessary only to pass water through the meters at various rates of flow, read the corresponding pressures on the two gages, and plot the differences of the two readings.

AWWA and NEWWA have established certain maximum head losses which may be sustained by various sizes and types of meters at specified rates of flow. For example, head loss in a ⅝-in. meter displacement meter is not to exceed 15 psi at a rate of flow of 20 gpm. Practically any ⅝-in. displacement meter will comply easily with this requirement.

Head loss tests are, in general, relatively unimportant in ordinary meter shop routine. Such tests are made by the manufacturer and the data are available to the purchaser upon request. The manufacturer will test a large number of meters of the same design and size, and the loss-of-head curve furnished generally is the composite result. There is very little variation in the loss of head in meters of the same type obtained from the same manufacturer, but there may be quite a difference in the losses in meters of different types or manufacture.

The head loss curves for displacement and current meters are similar in shape. The curves for compound meters, including fire line meters, are a combination of the typical head loss curves for the meters of which they are composed. The characteristic loss of head increases gradually from zero to a certain point, after which it falls off abruptly and then increases again as the flow rate increases. The first part of the curve represents the

loss of head through the displacement section of the compound meter as it passes the smaller rates of flow, the drop represents the head loss during the operation of the main valve, and the last part represents the head loss in the current section of the meter.

With fire line meters it is essential that head losses be kept to a minimum. NBFU requires that the loss through a fire line meter be extremely low in order to utilize the available system pressure as much as possible for the purpose of producing high fire flows. For flows within the capacity of the meter the NBFU specifies that head loss shall not exceed 4 psi. This is one reason why fire line meters measure only a proportion of the flow, permitting most of the flow at higher rates to pass unobstructed through the main body of the meter.

In a $\frac{5}{8}$-in. meter head loss is not an extremely important matter, although it does have some bearing on the delivery range of the meter. The $\frac{5}{8}$-in. size is the smallest obtainable, and the flows which pass through the ordinary $\frac{5}{8}$-in. meter rarely approach its full capacity. In the larger sizes of displacement meters and in all sizes of other types, loss of head is an important consideration. Meters with a comparatively low loss of head can be installed in smaller sizes without running at excessive speeds. At least one manufacturer designs $1\frac{1}{2}$-in. and 2-in. disc meters in such a way that they can be adjusted to meet high-pressure conditions which may result in high operating speeds. This adjustment merely throttles the discharge port, and produces an additional loss of head in the meter.

Applications of Various Meter Types

Displacement Meters

The best sizes of displacement meters for general use are $\frac{5}{8}$ in. to 2 in., although they are made up to the 6-in. size. Displacement meters are used where the rate of flow ranges from very low to fairly high and fluctuates considerably. One of the essential characteristics of this type of meter is its ability to measure very small rates of flow. It is the displacement meter section of the compound meter that makes it valuable for certain types of service. In general, displacement meters are domestic-service meters; in the larger sizes they are also ideally adapted to apartment house use.

Current Meters

Current meters are made in sizes ranging from $1\frac{1}{2}$ in. to 16 in., but the sizes in general use range from 2 in. to 10 in. A current meter is very rugged and not too difficult to maintain. It can pass great quantities of water at high rates of flow (within its capacity) with no damage to the working parts. It also has a comparatively low loss of head, which

is an ideal characteristic for a meter that must deliver high rates of flow. A 3-in. current meter becomes unreliable at flows less than 10 gpm, and flows of 2–3 gpm may pass through without registration. This type of meter is suitable for industrial lines, tanks fed by pumps at high rates, and similar classes of service.

General-Service Compound Meters

Compound meters are made in sizes ranging from 1½ in. to 12 in., but the sizes in general use are 3 in. to 8 in. This type is generally used where large quantities of water are used at comparatively high rates of flow, especially during certain periods, but where there is also some consumption at low rates. Loss of head is higher in compound meters than in current meters, but this cannot be avoided, because of the nature of its construction. Compound meters are more rugged than displacement meters and can undergo high rates of flow for long periods of time. They are generally used for services which would ordinarily be metered with current meters, were it not for the inability of the latter to measure low rates of flow.

Fire Line Meters

Fire line meters are made in sizes ranging from 3 in. to 12 in. As the name implies, they are designed strictly for fire line use where a large quantity of water under adequate pressure is necessary during a fire. Unusual installations have been made with this type of meter where the nature of the service called for the daily passage of great quantities of water under extremely low head loss.

Sizing of Meters

There is no hard and fast rule for selecting the correct size of meter for a particular service. It is true that a ⅝-in. meter will suffice for most jobs, but there is a limit to the capacity of such meters and the problem is to determine just how much water a ⅝-in. meter may be expected to measure with acceptable head loss. Many factors enter into this problem, and the answer depends greatly on local conditions.

Also involved in the selection of the correct size of meter is the question of what constitutes adequate service pressures and flows. In many instances, the lack of sufficient volume of water is erroneously blamed on the size of meter. Often it is actually traced to the inadequate size or condition of a tap, service pipe, or house plumbing. Occasionally the lack of adequate main pressures results in poor volume, and sometimes the only practical remedy is to install larger services and meters.

If certain facts are available relative to a proposed meter installation, it is not a particularly difficult task to select the correct type and size or

combinations of meters. The important factors to be given consideration are:

1. Pressure and quantity of water available in the main at the point of service connection
2. Differences in elevation between the street main and the highest water fixtures
3. Friction losses in the entire service line
4. Meter friction loss
5. Friction losses in house plumbing
6. Rates at which water is to be used.

As the water utility does not have responsibility for the entire service, the total friction losses must provide for reasonable losses within the premises as well as for elevation differences.

Testing and Maintenance of Meters

Water meters are subject to wear and deterioration and over a period of time lose their peak efficiencies. Several factors operate to cause wear, corrosion, deposition, and, thereby, inaccurate registration. Important among these are the chemical characteristics of the water being measured. From the customers' standpoint, meters should be tested to protect against overregistration and overcharge. Although overregistration is also of concern to the utility, it rarely occurs. The more normal result of meter deterioration is underregistration, which results in loss of revenue.

Meter Tests

Periods between tests are influenced by such factors as the rates charged for water, the effects of waters of different chemical characteristics, the cost of removing, testing, repairing, and reinstalling the meters. State regulatory commissions have adopted maximum periods between tests for most privately owned water utilities and for some publicly owned systems. These periods generally are expressed in maximum number of years between tests for various sizes of meters sometimes with an overriding period based upon a maximum quantity of water passing through the meter. The maximum period for $\frac{5}{8}$-in. meters ranges between 3 and 10 years with 5- and 10-year periods being most common. For meter of sizes $\frac{3}{4}$ in. through 3 in. the period ranges from 2 to 8 years, and on 4 in. or larger it ranges from 1 to 4 years.

The equipment required to test a water meter may be very simple. The test procedure may consist simply of timing the flow through a meter set in the line discharging into a tank on a set of scales to weigh the water. An orifice may sometimes be used. Where the number of meters to be tested warrants, more suitable test equipment is commercially available.

Maintenance and Repair

The maintenance and repair of positive-displacement meters consists essentially of dismantling, thoroughly cleaning, and inspecting all parts. After dismantling, the measuring chamber should be carefully inspected for pitting, and the moving parts and appurtenances, such as the disc, thrust rollers, and slots, checked for excessive wear and corrosion. The disc should be checked with straightedge and examined for swelling and distortion caused by freezing, heat, or hot water.

After defective and badly worn parts have been replaced, the disc should be reassembled in the chamber. Proper clearances should be provided and shims should be inserted if required. The gear train should run freely and mesh smoothly, and spindles should be checked for wear and bushed if required. Gear teeth should be examined for wear.

Some of the important points to remember in meter maintenance are:

1. Clean all meter parts thoroughly
2. Make sure the gear train runs freely
3. Check the action of the disc in the chamber before and after assembly in the main casing
4. Remember that friction is just as detrimental to correct registration as slippage
5. Store meters away from heat
6. Use a new meter as a standard of comparison for tolerances and clearances
7. Retest the meter for accuracy after repair
8. If necessary, call upon the manufacturer for advice and help.

The maintenance and repair of other types of meters follow essentially the same procedure, the differences largely resulting from the variations in construction.

Efficiency is promoted by determining the best means of travel of the meter through the repair shop in carrying out the various elements of testing, maintenance, and repair.

CHAPTER 8

System Maintenance and Control

A VERY necessary element in the efficient operation of a water distribution system is a good preventive- and corrective-maintenance program. Such a program is necessary to:

1. Prevent failure of facilities
2. Detect and eliminate weak links in the system
3. Determine the type and quantity of materials and replacement parts to be stockpiled for repairs
4. Analyze how distribution facilities stand up in actual operation as a guide for future installations
5. Maintain good public relations by making needed repairs before damage and interruption to service occur
6. Detect and eliminate safety hazards
7. Distribute work load more advantageously
8. Reduce the cost of maintenance.

System Inspection

Mains

Because water mains are buried and rarely uncovered or exposed, a comprehensive and systematic routine checking procedure cannot ordinarily be carried out. Nevertheless, by keeping leakage and breakage records, and by making pressure, flow and pipe coefficient surveys, incipient failures or deficiencies in service can often be recognized and corrected in advance.

Distribution and installation crews, even meter readers and servicemen, should be instructed to note and report any unusual or special conditions which they discover in their routine work. When wet connections are made or valves are inserted in pipelines, the coupons cut from the pipe should be observed to note the interior condition of the pipe. If deemed advisable, the coupons should be saved and be properly identified.

Proper records should be kept of pipe breakage, leak surveys, and pressure and coefficient tests to aid in making decisions relating to maintenance, retirement, and replacement of facilities.

Valves

A well organized valve inspection program is essential to proper operation. In the larger systems such inspection may well form the responsibility of a special crew doing such work continuously. In smaller systems

the distribution crew may have to be assigned for a definite period for a particular type of work.

Valves are provided in a distribution system principally to isolate small areas for emergency maintenance. Thus, most distribution valves suffer from lack of operation rather than from wear. No hard and fast rules can be set up as to how often valves in different parts of the system should be operated for test purposes. The corrosiveness of the water, the rate of deposition of sand or other solids, and the sizes and locations of the valves all have a bearing on the desirable frequency of operation. In a normal system, valves larger than 12 in. should be operated at least once a year. Valves 12 in. and smaller should be operated at least once every 3 years, and critical valves should probably be operated more often. Valve boxes or vaults located in streets subject to frequent maintenance should be checked annually to see that they are not damaged, filled with earth, or covered over with pavement.

The following procedures should be followed in a proper valve inspection program:

1. The location and measurements to recorded reference points should be checked.

2. Valves should be operated in both directions, fully closed and fully opened, and the number of turns and direction of operation should be noted. Particular care should be taken to identify valves that operate in the opposite direction to that which is standard for the system. The use of portable power-actuated valve operators is generally economically feasible for all but the smallest systems.

3. Valves should normally be left in the open position but any valves required to be closed should be carefully noted.

4. Badly corroded valves should be operated several times, and, if necessary, flow should be induced by opening a hydrant to flush out valve seats.

5. The condition of the valve packing, stem, stem nut, and gearing should be noted.

6. Valve boxes or vaults should be checked; cleaned out; and raised, lowered, or replaced, as required.

Most systems number the valves consecutively for quick identification and keep a record of the location, type, size, make, and time of installation.

Hydrants

Fire hydrants, like valves, are installed essentially for emergency use and should have a regularly scheduled checking program. Hydrants are particularly vulnerable to damage and failure, because they are exposed. In general, all hydrants should be checked at least once annually. In most systems they are checked and operated twice a year, in the fall and in the spring. The correct inspection procedure is outlined below:

1. The hydrant should be sounded for leaks.
2. It should be operated and flushed, the ease or difficulty of operation noted, and any worn or loose parts remedied.
3. The condition of the drain valve, operating nut, nozzles, nozzle caps, chains, packing, and paint should be noted.
4. After operation and closure, the interior should be observed to see if the barrel drains properly.
5. The setting of the hydrant and the distance of the nozzles from the ground and curb line should be noted and remedied if not acceptable.
6. The hydrant should be lubricated.
7. The accessibility of the hydrant, ground clearance, and interference from poles or other objects should be noted and corrected if necessary.

Frequent painting of fire hydrants is an excellent public relations tool, inasmuch as hydrants are usually the only element of the distribution system seen by the general public and thereby able to create a favorable impression.

Customer Services

The checking of services and meter installations is generally a function which the meter readers and servicemen are best able to perform, monthly or quarterly, on their customary rounds. Generally, little can be done in checking the buried portion of a service line. The condition of the meter or curb box should, however, periodically be checked and maintenance should be carried out if required. One of the most frequent sources of suits against a utility is injury caused by tripping over a projecting meter or curb box. Meter readers should be alerted and instructed to report any such displacement for prompt remedy.

Leaking services are another element of distribution reporting which the meter reader can best perform in his regular round of duties.

If the system has some flat-rate customers or inactive metered services, a program of periodic inspections of them should be established.

The condition of the customers' meters and the meter installations are other elements of distribution system inspection which the meter reader should perform and report on. An alert meter reader can often spot under-registering meters by a quick comparison with past readings. Meter stoppages should be picked up immediately at the time of meter reading.

Pavement Breaks

Pavement breaks cannot be completely eliminated in the average distribution system. They are an element of operation which probably generates as much ill will towards the utility as any other single cause. The first requirement of proper repair is speed in effecting it. A stable backfill of the trench is imperative. Temporary pavement surface should immedi-

ately be provided upon completion of trench backfill. Generally arrangements are made with responsible paving contractors to effect a permanent pavement replacement as soon as practical. In a large system the repaving may be done effectively and efficiently by the utility's own maintenance crew.

Sanitary Checks

One of the most important phases of proper distribution system operation is to make certain that water leaving the supply works in acceptable sanitary and aesthetic condition remains so until it is delivered to the ultimate customer. Sampling stations should be established at several points

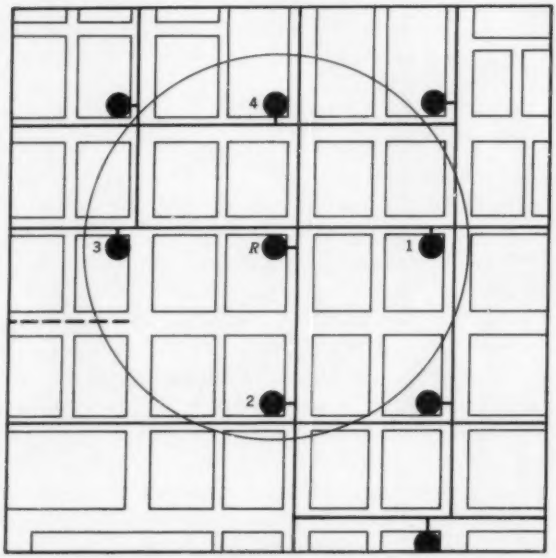

Fig. 8.1. Typical Group Hydrant Flow Test

in the distribution system, the number depending on the size and extent of the system, and periodic samples of water should be collected and tested to form a continuous monitoring system.

Most state boards of health require that this be done, but, even if they do not, every water utility should have a monitoring procedure in order to keep a constant check on the effects of time, travel, and the condition of the mains upon the quality and physical condition of the water. Not only should the standard bacteriologic tests be performed, but it is also

advisable to keep check on the chlorine residual, as well as such chemical qualities as iron and manganese content, pH, and hardness and such physical properties as turbidity, color, taste, and odor.

APHA, AWWA, and WPCF have collaborated in promulgating *Standard Methods*,* which sets forth the methods of examination of samples. The USPHS Drinking Water Standards † set forth the limits of bacteriologic, chemical, and physical quality of water permitted on interstate carriers subject to federal quarantine regulation. These limits are commonly followed in water supply practice.

Pressure Tests

Pressure tests in a water distribution system are commonly carried out by attaching a pressure gage to a hose nozzle of a hydrant, opening the hydrant, and reading the pressure. A pressure record of greater duration can be secured by using a recording pressure gage. It is sometimes advantageous to have several points in the system continuously monitored for pressure so as to evaluate the operation of the system, especially during days of maximum drafts.

Flow Tests

Flow tests are important to determine the efficiency and adequacy of the distribution system in transmitting water, particularly during days of peak demand, and to determine the amount of water available from hydrants for fire fighting. To make such tests it is necessary to induce a flow from one or more hydrants, measure the flow from the hydrants, and note the change in pressures from no flow to full flow at a nearby hydrant. Figure 8.1 shows a group hydrant flow test in which Hydrants 1, 2, 3, and 4 were flowed simultaneously and the residual pressure under such flow was read at Hydrant *R*. To determine flows from the hydrant, a hydrant pitot gage may be used. This is an instrument with a tube having a small hole in one end which is centered in the stream flowing from the hydrant nozzle, the velocity of flow is transmitted as pressure to a pressure gage attached to the tube. A pressure gage attached to one hose nozzle of a hydrant with flow being induced from another nozzle of the same hydrant registers substantially the same as a hydrant pitot gage, and it is considerably easier to perform such a test with a pressure gage such as that shown in Fig. 8.2.

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* *Standard Methods for the Examination of Water and Wastewater.* APHA, AWWA & WPCF. Am. Wtr. Wks. Assn., New York (1960).

† US PUBLIC HEALTH SERVICE. Drinking Water Standards, 1961. *Jour. AWWA*, 53:935 (Aug. 1961).

Calculations

From the pitot or pressure gage reading, the pressure p (in pounds per square inch), the diameter of the nozzle D (in inches), the hydrant discharge rate Q (in gallons per minute) can be found in appropriate tables or computed from the formula $Q = 27\,D^2\sqrt{p}$.

NBFU generally prescribes that there should be a certain flow at a test location with a residual pressure of 20 psi.* It is necessary, therefore, to adjust the actual readings to determine the flow which would be available with a residual pressure of 20 psi in a nearby hydrant. This is done by using the formula

$$Q_A = Q_T \frac{h_A 0.54}{h_T 0.54}.$$

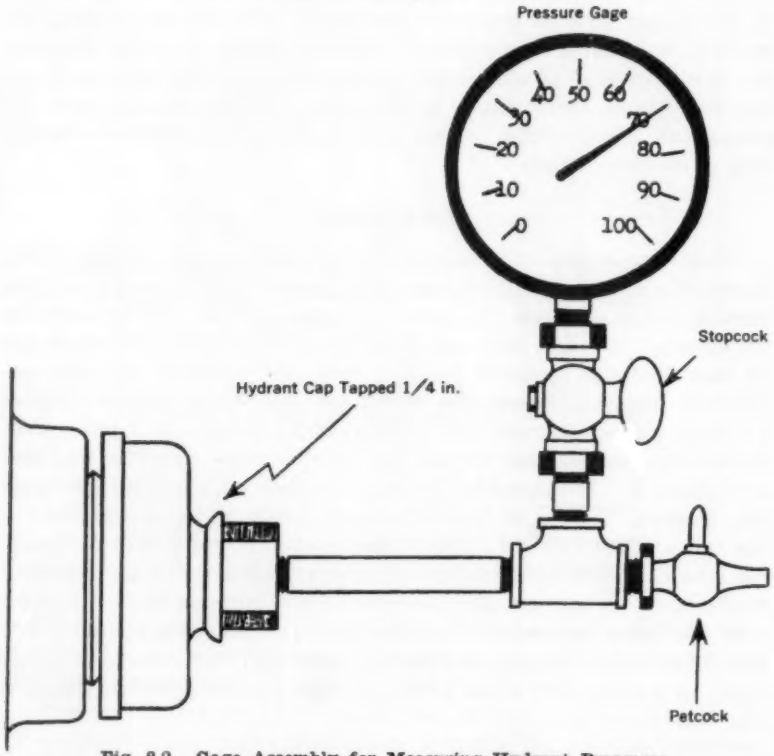

Fig. 8.2. Gage Assembly for Measuring Hydrant Pressures

* *Standard Schedule for Grading Cities and Towns of the United States With Reference to Their Fire Defenses and Physical Conditions.* Natl. Board of Fire Underwriters, New York (1956). p. 36.

in which Q_A is the flow available with a residual of 20 psi, Q_T is the test flow, h_A is the pressure drop available, and h_T is the pressure drop during test. It is sufficiently accurate in most tests to write this equation as

$$Q_A = Q_T \sqrt{\frac{h_A}{h_T}}.$$

For example, in Fig. 8.1, if the nozzle in Hydrant 1 is $2\frac{1}{2}$ in. inside diameter, and the pressure gage reads 15 psi, the flow is $Q = 27 \times 2.5^2 \times \sqrt{15} = 654$ gpm. The simultaneous flow readings of all four hydrants produced a total flow of 2,200 gpm. At this flow the residual pressure at Hydrant *R* dropped from 90 psi to 58 psi, a difference of 32 psi. The adjusted flow, with a residual of 20 psi, is thus

$$Q_A = 2{,}200 \sqrt{\frac{90 - 20}{90 - 58}} = 3{,}260 \text{ gpm}.$$

If the 0.54th power had been used instead of the 0.5th power, Q_A would have been 3,350 gpm, less than a 3 per cent difference. Hydrant flow tests should be conducted at such times as will cause the least inconvenience to the public. Flow periods should not exceed 2 min.

Hydraulic-Gradient Tests

Hydraulic-gradient tests are generally run to determine the ability of the distribution system to transmit the water with adequate residual pressures. In other words, the aim of these tests is to find any weaknesses in the system. The tests normally are run during periods of peak delivery. They should, however, be run during a period when the system flows are substantially constant—that is, during the midmorning or midafternoon.

The tests are made by taking pressure measurements at various points in the system, generally located in sequence along a line from the source of delivery to the outlying sections. Normally the measurements are plotted with respect to a vertical scale with a distance scale as the abscissa. The curve connecting the plotted measurements gives a visual picture of the losses of head between points as the water is distributed to the outlying points. The slope of the gradient reveals the sections where the greatest friction losss occur.

Coefficient Tests

Coefficient tests are occasionally run to determine the condition of the pipelines, insofar as factors causing friction losses are concerned. A certain section of pipe is isolated to the greatest extent possible, even to closing service connections, and the hydraulic gradient is determined between two points a known distance apart and the normal or induced flow

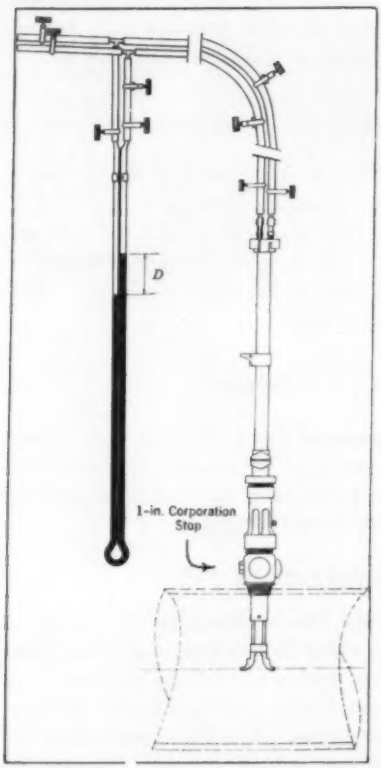

Fig. 8.3. Modified Pitot Meter

through the pipeline is measured. With these data, the coefficient can be computed from the Hazen-Williams formula. Once the coefficient has been determined for that particular section the head loss under other flows can be computed.

The measurement of flow can be made by hydrant flows such as previously described, assuming that a complete isolation of the section can be accomplished. If not, the flow measurement can be made by a pitot meter (Fig. 8.3) or a venturi meter (Fig. 8.4). Both of these instruments are accurate and quite easy to operate. The flow of water through the venturi meter results in a reduction in pressure at the constriction in the meter. The difference between the pressure at the constriction and in the unconstricted portion of the conduit is a function of the flow rate and is used to calculate the latter.

The determination of flow by the pitot meter depends upon translating the difference (D) between static and flowing head into an ap-

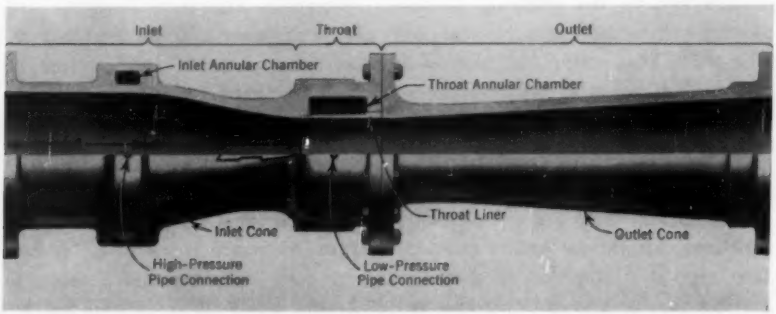

Fig. 8.4. Venturi Tube

proximate discharge figure. Two small tubes are inserted into a pipeline through a 1-in. corporation stop. The two small bent tubes forming the instrument are turned, one pointing against the flow and the other in the opposite direction. They are connected to a differential-pressure measuring device. The deflection resulting from pointing one tube into the flow and the other with the flow provides a measurement of the velocity of the water at the center of the pipe. Means are provided to compute the average velocity in the pipe by a relationship between quantity, velocity, and pipe area. Instruction should be secured from the supplier as to the operation of the pitot meter rod.

Pressure Gages

Most of the tests described above require the use of pressure gages. Pressure gages are commonly carried around in service trucks and receive rough treatment. They do not retain their accuracy for long under such treatment. Frequent testing of pressure gages, whether used in the plant or in distribution testing, is an absolute necessity for accurate results. Pressure gages are generally tested by using a dead-weight tester such as that shown in Fig. 8.5 or by comparison with reliable test gages. For important surveys in which the accuracy of the test gages is very important, they should be tested both before and after use. The testing of main line or customer's meters is covered more fully in Chapter 7.

Leak Surveys

Leak surveys of the distribution system are sometimes advantageous if accounted-for water increases without apparent reason. The amount of unaccounted-for water which might be acceptable is dependent largely upon the conditions existing in each system. It might be 25 per cent in one system whereas an amount in excess of 10 per cent in another system might indicate excess leakage or a large underregistration of meters. Included in such percentages is any water delivered to the system but not metered, or included in a reasonable estimate for flat-rate customers.

Conditions which affect the amount of unaccounted-for water are pressures and variation of pressures throughout the system; the length, condition, and age of pipe system and service lines; efficiency of meter maintenance; ratio of large users to total service; soil conditions; and the attention given to leakage reduction and unauthorized uses of water. A system pressure of 100 psi produces much more leakage than a pressure of 50 psi. High pressures also increase the underregistration of meters. The length, condition, and age of the pipe system and service lines affect losses through broken or corroded pipe or joint leaks. Soil conditions may make locating

leaks easy or difficult. In some soils the leakage disappears without coming to the surface, thus making it extremely difficult to discover the losses. Underregistration of meters is increased by improper maintenance and long periods between tests. If a system has a high percentage of industrial or commercial use, the unaccounted-for percentage tends to be lower because the total water sold is weighted with larger units.

Leak surveys are accomplished in several ways. Leak survey crews can inspect the system with geophones or electrical detector equipment and listen for service and distribution system leaks. Hydrant leaks through

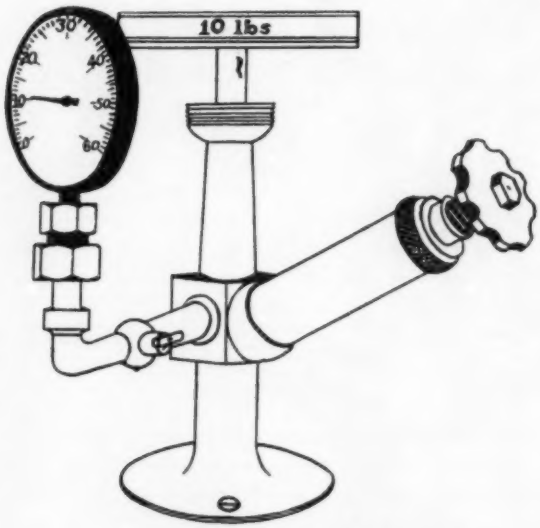

Fig. 8.5. Dead-Weight Pressure Gage Tester

improper drain valves are common and can generally be discovered in this way.

Generally speaking, when the term "leak survey" is used, it refers to a comprehensive survey accomplished by subdividing the system into districts and controlling and measuring the flow into such districts for at least 24 hr and comparing the night rate to the total 24-hr use. If the night rate indicates high usage which cannot be explained satisfactorily, leakage probably exists. By a process of further subdivision the location of the source of the high night rate can be discovered.

Measurement of flows is accomplished by recording pitot meter readings over a 24-hr period. Qualified firms are customarily retained to carry

out such surveys, for the work is quite technical and the normal system is not equipped or properly manned to do it. Leak surveys should be made in most systems whenever the unaccounted-for water exceeds 20–25 per cent.

Equipment and Stores

Careful attention should be given to the selection of the proper tools and equipment for distribution system maintenance. The number and variety of tools and equipment are generally dependent on the size of the utility. In the selection of tools and equipment the following points should be considered:

1. Economic and efficiency value of the equipment, including any reduction of labor cost
2. Public relations value of the equipment in reducing the duration of service interruptions
3. Improvement of employee morale and standards of labor
4. Usefulness of the tools or equipment for construction and installation of facilities as well as maintenance.

For efficient operation and maintenance, an adequate stockpile of commonly used materials, supplies, and replacement parts is essential. A careful analysis of the system requirements should be made to determine what and how much should ordinarily be kept on hand. A perpetual stock inventory should be kept and should include separately new and salvaged materials and equipment. The most carefully planned stock inventory is of little value unless stock is properly classified, described, and identified and can be easily located.

The essential information to be included in a perpetual inventory system consists of:

1. A description of items
2. A continuous record of the quantity of each item in stock
3. Identification of each item as to the quantity, date ordered, and purchase order number
4. A record of receipts into stock by quantity, date, and source
5. A record of disbursements from stock by quantity, date, and purpose
6. A record of the unit costs of items
7. A record of the location of items in stores.

A physical inventory of stock should be made at periodic intervals, once or twice a year.

System Records

In order to operate and maintain a water distribution system efficiently, it is essential that adequate records of all details of the system be established

INVESTMENT WORK ORDER

FOR PROPERTY ADDITIONS AND IMPROVEMENTS

Investment Work Order No. A-80

Charge to Budget (Item C Below) $ 1,652.65

The Metropolitan Water Company
Name of Company

Apply to Budget Item No. 1A-2

Metropolitan City
Location

File No. -443

DESCRIPTIVE TITLE: Install 400 feet of 6" asbestos-cement pipe on Main Street south from First Avenue.

PURPOSE: Give complete explanation here, not by letter. Attach extra sheet if necessary. Sketch must accompany changes in distribution system, buildings, pumping equipment and piping. If contribution or refundable deposit toward the cost is to be obtained, state amount thereof, from whom it will be received, and if an agreement is to be entered into submit the signed agreement. If State regulations, franchises, municipal contracts or company rules are involved, state extent.

This installation required to replace a 3/4" galvanized pipe installed in 1926, which has become inadequate due to corrosion and an increased number of customers.

Pressure on Proposed Mains 60 psi Traffic light Type of Paving none

SUMMARY ESTIMATE OF COST

A. Total estimated cost (per reverse)	$ 1,652.65
B. Less: Contributions (non-refundable)	$
C. Net direct cost to Company	$ 1,652.65
D. Service and meter installations	$
E. Total cost	$ 1,652.65

If any preliminary investigation costs have been incurred for this project, to what account were they charged? None

Does the proposed work replace any Company owned property? Yes

If yes, what number is assigned to the related Retirement Order? R - 31

In what political subdivision will new property be located? Metropolitan City

RETURN ON INVESTMENT

1. Total investment cost (Item E)	$ 1,625.65
2. Increase in revenue:	
2a. ____ Consumers @ $ ____	$
2b. ____ Consumers @ $ ____	
2c. ____ Hydrants @ $ ____	
2d. ____	
3. Total increase in revenue	$
4. Decrease in operating expenses	
5. Total—Lines 3 and 4	
6. Increase in expenses:	
6a. Operating, maintenance and general taxes, ____% of Line 3	$
6b. Depreciation ____% of Line 1	
7. Total increase in expenses	
8. Income before income taxes—Line 5 minus 7	
9. Income taxes ____% of Line 8	
10. Income available for return—Line 8 minus 9	$
11. Rate of return—Line 10 ÷ Line 1	%

PREPARATION AND APPROVAL

LOCAL AND DIVISION OFFICES		Date
Prepared By:		
Local Manager:		
Budget Approval:		
Division Comptroller:		
Division Manager:		

GENERAL OFFICE		Date
Prepared By:		

Fig. 8.6. Sample Investment Work Order Form

and be kept up to date. Accurate maps showing the locations of mains, valves, hydrants, and other accessories to the distribution system are important elements of these records. Records should do more than define the location of the physical elements, however. The forms and procedures should be designed to provide the basic data on physical assets in conjunction with the system of continuing property records required by various regulatory agencies. Even in municipally owned plants, a system of records should be devised to account properly for the physical plant. A work order system should provide that all additions or changes to, or removal of, physical elements of plant be accomplished through the medium of approved work orders.

Typical Work Order System

Typical operating forms and records of a proper work order system might generally consist of:

1. Investment work order (Fig. 8.6)
2. Retirement work order
3. Work order sketch (Fig. 8.7)
4. Work authorization
5. Work order completion sketch
6. Distribution system map and sectional maps
7. Street intersection drawings
8. Valve register
9. Hydrant register
10. Tap-service order
11. Service record
12. Report of materials installed on blanket work orders
13. Report of materials retired on blanket work orders
14. Service envelope
15. Record of meters purchased
16. Meter envelope
17. "Material issued" report
18. "Material received and issued" report
19. Valve inspection report (Fig. 8.8)
20. Hydrant inspection report (Fig. 8.8)
21. Service orders
22. Report of meter test and repair.

Examples of some of these work forms are shown in Fig. 8.6–8.8. In addition to these records, repair and maintenance records of such elements as pumping equipment, distribution storage, and work and transportation equipment should be maintained.

Use of System

Typical procedure in using these records should be somewhat as follows. Upon issuance of a work order, a work authorization should be prepared to cover the work involved and issued to the person responsible for carrying out the work. Actual construction work should not commence until receipt of an approved work order. A copy of the work

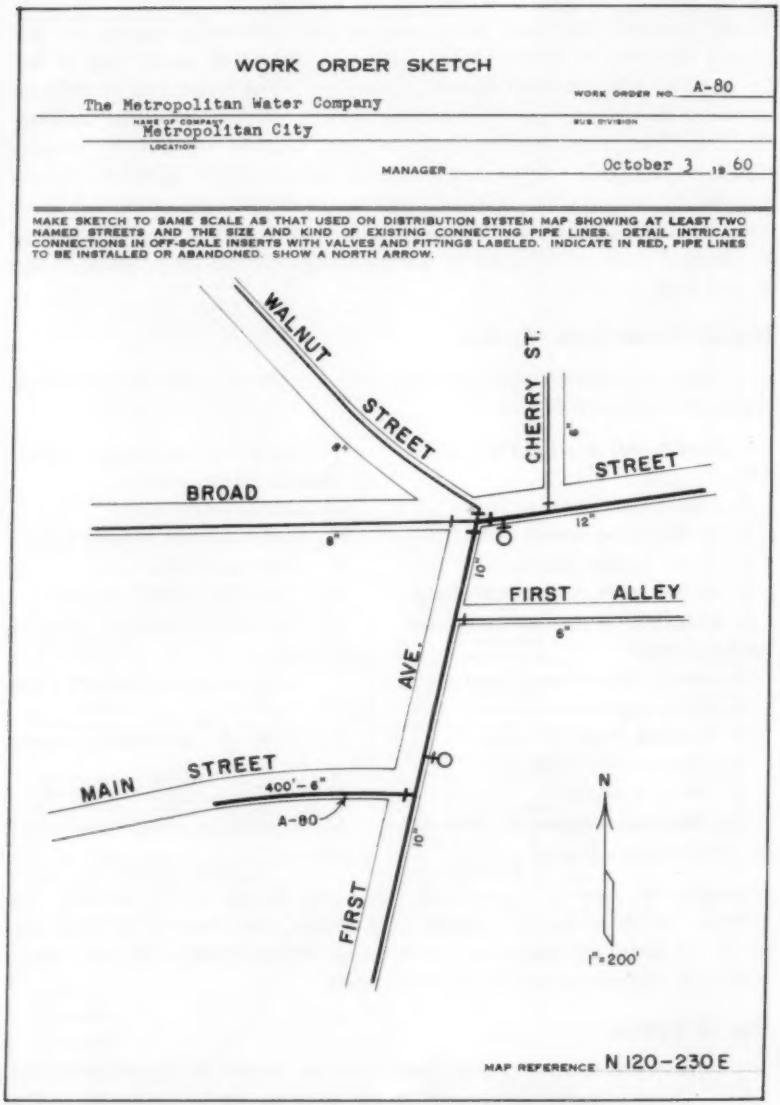
WORK ORDER SKETCH
The Metropolitan Water Company
NAME OF COMPANY
Metropolitan City
LOCATION
WORK ORDER NO. A-80
SUB. DIVISION
MANAGER
October 3 19 60
MAKE SKETCH TO SAME SCALE AS THAT USED ON DISTRIBUTION SYSTEM MAP SHOWING AT LEAST TWO NAMED STREETS AND THE SIZE AND KIND OF EXISTING CONNECTING PIPE LINES. DETAIL INTRICATE CONNECTIONS IN OFF-SCALE INSERTS WITH VALVES AND FITTINGS LABELED. INDICATE IN RED, PIPE LINES TO BE INSTALLED OR ABANDONED. SHOW A NORTH ARROW.
WALNUT STREET
CHERRY ST.
STREET
BROAD
FIRST ALLEY
AVE.
MAIN STREET
400'-6"
A-80
FIRST
N
1"=200'
MAP REFERENCE N 120-230 E

Fig. 8.7. Sample Work Order Sketch

VALVE INSPECTION REPORT

MUNICIPALITY _____ VALVE NO. _____

LOCATION _____

SIZE _____ MAKE _____ OPER. NUT _____

OPENS _____ NO. TURNS _____

VALVE IN _____ ROUTE NO. _____

CONDITION	INSPECTION DATES					
OPENS						
NO. TURNS						
STEM						
PACKING						
NUT						
BOX or MANHOLE						
VALVE is NOW						
INSPECTED BY						

CONDITION	INSPECTION DATES					
OPENS						
NO. TURNS						
STEM						
PACKING						
NUT						
BOX or MANHOLE						
VALVE is NOW						
INSPECTED BY						

CONDITION	INSPECTION DATES					
OPENS						
NO. TURNS						
STEM						
PACKING						
NUT						
BOX or MANHOLE						
VALVE is NOW						
INSPECTED BY						

HYDRANT INSPECTION REPORT

MUNICIPALITY _____ HYD. NO. _____

LOCATION _____

MAKE _____ SIZE _____

2½" NOZZLES _____ STEAMER NOZZLES _____

OPENS _____ SIZE MAIN _____ SIZE BRANCH _____ BRANCH VALVE _____

CONDITION	INSPECTION DATES					
PAINT						
CAPS						
CHAINS						
STEM						
PACKING						
DRIP						
TOP NUT						
VALVE						
VALVE SEAT						
CONDITION of WATER						
MINUTES FLUSHED						
STATIC PRESSURE						
RESIDUAL PRESSURE						
FLOW						
INSPECTED BY						

CONDITION	INSPECTION DATES					
PAINT						
CAPS						
CHAINS						
STEM						
PACKING						
DRIP						
TOP NUT						
VALVE						
VALVE SEAT						
CONDITION of WATER						
MINUTES FLUSHED						
STATIC PRESSURE						
RESIDUAL PRESSURE						
FLOW						
INSPECTED BY						

Fig. 8.8. Valve and Hydrant Inspection Report Forms

order sketch, showing the scope of the work, should be attached to the work authorization. Upon completion of the work it is essential that detailed diagrams with exact location measurements of all mains, valves, hydrants, and blowoffs be made on the reverse side of the Work Authorization. Hydrant and valve numbers should be assigned, entries made in the hydrant and valve registers, and the completed work order sketch prepared.

Materials used should be posted to the "materials isssued" report from which the materials are to be withdrawn from stock and entry made on the "materials received and issued" report for the month in which the materials were incorporated in the installation. Upon completion, the work authorization should be placed in an envelope on which the work order number is noted, and filed in numerical sequence.

The work order completion sketch is utilized to revise the distribution maps to record additions, changes, or removals.

Every public and private hydrant and every valve should be numbered, and the installation and location data pertaining to them should be posted to the proper hydrant and valve registers.

In more complex systems or parts of systems, numbered street intersection drawings for field use, showing detailed measurements of valves and hydrants, may be desirable for inclusion in the valve registers. The numbered street intersection drawings should be shown on the pipe maps for ready identification.

Every service installation, replacement, or "kill" (removal) should be be accomplished by a tap service order, properly numbered.

Every purchase of meters should be posted directly on the record of meters purchased from the monthly "material received and issued" reports. Meter installations should be made on issuance of a work authorization.

It is desirable to secure a good topographic map of the area presently served by the distribution system as well as areas surrounding the service area in order to plan future extensions. Street and subdivision maps are also useful data to have at hand.

In addition to these standard forms, there are certain special records which should be kept to form a complete picture of the operation and maintenance of the distribution system and the cost involved. Among such records are pressure, flow, breakage and leakage records; records of fire hydrant use, main maintenance and cleaning; and records of water quality at a number of points in the system.

81st Annual Conference
Cobo Hall, Detroit, Mich.
June 4–9, 1961

Convention Committees

Convention Management Committee

Representing AWWA

Gerald Remus, *Chairman*

H. O. Self — T. L. Vander Velde

Representing WSWMA

E. D. Barrett — H. G. Tiedeman

Ex Officio

C. F. Wertz, *President AWWA*
R. J. Faust, *Executive Secretary AWWA*
E. Shaw Cole, *Chairman AWWA Technical Committee*
C. V. Roberts, *President WSWMA*
J. G. Stewart, *Manager WSWMA*

Convention Place Committee

Representing AWWA

Lauren W. Grayson, *Chairman*

C. F. Wertz — Raymond J. Faust

Representing WSWMA

George W. Kelsey — C. V. Roberts
John G. Stewart

Technical Program Committee

E. Shaw Cole, *Chairman*

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Robert Blair, *Vice-Chairman*

Captains

G. A. Dehem — H. L. Keinath
Robert Haw — J. M. Rogeven
G. D. Heggie — J. B. Thompson

Crew

W. H. Abbott Jr. — L. J. Lamb
E. P. Ahles — H. T. Lane Jr.
H. M. Britz — J. V. Lockwood
F. H. Burley — E. A. Loft
Ernest Cedroni — T. A. Lyons
H. D. Cisco — H. P. MacLennan
H. F. DeMott — J. R. Metz
J. F. Dye — A. L. Mulheisen
Michael Garnell — T. R. Myers
R. E. Hansen — G. J. O'Brien
D. E. Hazelswart — J. L. Powell
G. J. Hazey — W. J. Redman
W. A. Herrscher — J. C. Richardson
V. L. Hinebrook — R. W. Steventon
D. N. Knight — G. E. Tennant

Publicity Committee

L. G. Keller, *Chairman* — K. Day

Local Transportation Committee

G. A. Sochowicz — T. Standen

1961 CONFERENCE STATISTICS

Detroit Registration by Days

	Men	Ladies	Total
Preregistration	1,095	282	1,377
Sunday, June 4	575	196	771
Monday, June 5	732	159	891
Tuesday, June 6	277	20	297
Wednesday, June 7	214	—	214
Thursday, June 8	141	—	141
TOTALS	**3,034**	**657**	**3,691**

Geographic Distribution of Registrants

UNITED STATES		Massachusetts	46	Tennessee	48
Alabama	48	Michigan	758	Texas	66
Arizona	11	Minnesota	46	Utah	4
Arkansas	14	Mississippi	11	Virginia	31
California	144	Missouri	104	Washington	15
Colorado	24	Montana	4	West Virginia	13
Connecticut	23	Nebraska	25	Wisconsin	61
Delaware	7	New Hampshire	2	Wyoming	1
Dist. Columbia	18	New Jersey	149	**CANADA**	
Florida	49	New Mexico	6	Manitoba	4
Georgia	42	New York	309	Nova Scotia	2
Hawaii	3	North Carolina	18	Ontario	175
Illinois	319	North Dakota	6	Quebec	15
Indiana	142	Ohio	302	Saskatchewan	2
Iowa	66	Oklahoma	7	**FOREIGN**	
Kansas	46	Oregon	17	Asia	5
Kentucky	36	Pennsylvania	321	Europe	10
Louisiana	19	Puerto Rico	7	Latin America	8
Maine	4	Rhode Island	11		
Maryland	42	South Carolina	16	**TOTAL**	**3,691**
		South Dakota	9		

Comparative Registration Totals—1952–1961

Year	Place	Men	Ladies	Total
1961	Detroit	3,034	654	3,691
1960	Bal Harbour	2,157	879	3,036
1959	San Francisco	2,426	785	3,211
1958	Dallas	2,337	687	3,024
1957	Atlantic City	2,398	669	3,067
1956	St. Louis	2,026	510	2,536
1955	Chicago	2,075	512	2,587
1954	Seattle	1,536	527	2,063
1953	Grand Rapids	1,532	365	1,897
1952	Kansas City	1,600	386	1,986

Win, Place & Show in Section Awards

Henshaw Cup		Hill Cup		Old Oaken Bucket	
Rocky Mountain	**75.6%**	**Wisconsin**	**76.224**	**California**	**1,678**
Pacific Northwest	71.9%	Florida	33.592	Southwest	1,091
Montana	71.4%	North Central	24.256	New York	907

Inspection Trips Committee

Robert Blair, *Chairman*

F. H. Burley
G. A. Dehem
J. V. Lockwood
T. A. Lyons

Meet and Greet Night Committee

A. C. Michael, *Chairman*
Tony Eikey, *Vice-Chairman*
H. O. Self, *Honorary Chairman*

S. H. Bogue
M. B. Deo
C. R. Erickson
J. W. Gable
G. H. Strickland
J. E. Vogt

Awards and President's Reception

Honorary Chairmen—Awards

C. F. Wertz
J. G. Copley
P. S. Wilson

Honorary Chairmen—Reception

Mr. and Mrs. L. W. Grayson
Mr. & Mrs. L. S. Finch
Mr. and Mrs. Fred Merryfield

Local Committee

A. M. Shannon, *Chairman*
G. J. Hazey, *Vice-Chairman*
T. L. Vander Velde, *Honorary Chairman*
L. E. Ayres, *Honorary Chairman*
Tony Eikey, *Honorary Chairman*

G. R. Bingham
Ernest Cedroni
Sidney DeBoer
D. C. Egbert
J. J. Eilers
R. E. Hansen
James Hornung
Anton Kovochich
W. A. Royce
Steven Georgeff

Golf Tournament

W. R. Augustine
M. A. Bartley
T. A. Lyons

Carnival

E. M. Rasinen, *Chairman*
E. J. Eddy, *Vice-Chairman*

H. M. Britz
W. E. Busse
K. E. Garvey
W. A. Herrscher
R. L. Johnson
Albert Sabo
A. H. Tolley

Banquet and Ball

E. D. Barrett, *Chairman*

J. E. Cooper
E. J. Highstreet
H. L. Keinath
G. E. Matthews
J. R. Metz
F. J. Pipp
J. M. Rogeven

Ladies Entertainment Committee

Mrs. Gerald Remus, *Chairman*

Local Hostesses

Mrs. Henry Tiedeman, *Chairman*
Mrs. Robert Blair, *Co-Chairman*

Luncheon-Fashion Show—Mrs. A. M. Shannon & Mrs. E. M. Rasinen, *Co-Chairmen*
Art Center Tour—Mrs. A. C. Michael, *Chairman*
Cranbrook Tour—Mrs. Joseph Gabel, *Chairman*
Bar-B-Q & Tour—Mrs. E. J. Eddy & Mrs. E. D. Barrett, *Co-Chairmen*
Sugar 'n Spice Breakfast—Mrs. M. A. Bartley, *Chairman*

Association Awards

Honorary Membership

Honorary Membership was conferred upon Ray L. Derby, Otto E. Eckert, Attmore E. Griffin, and Fred Merryfield. The citations follow:

Ray Lyle Derby, Princeton Sanitary Engineer, Los Angeles Department of Water and Power: *Member of the Association since May 1926; long active in Purification Division affairs; Diven Medal 1958: for his outstanding contributions to the art of water treatment control and his years of unselfish effort in the improvement of methods of analysis and the control of cross connections.*

Otto Elis Eckert, General Manager, Board of Water and Electric Light Commissioners, Lansing, Mich.: *Corporation representative since June*

D. L. Derby

O. E. Eckert

A. E. Griffin

F. Merryfield

1929: for his exemplary performance as a water utility manager, which has given leadership and inspiration to countless water works men over the years.

ATTMORE E. GRIFFIN, Water Treatment Consultant, Pompton Plains, N.J.: *Member of AWWA since May 1930; an active worker on committees of the Purification Division; Fuller Award 1944: for his long-time participation in and encouragement of research in the water works field and his generous expenditure of time on Association affairs.*

FRED MERRYFIELD, Professor of Sanitary Engineering, Oregon State College, Corvallis, Ore.: *Member of the Association since 1934; Director 1950–53 and 1959; Vice-President 1957; President 1958; Fuller Award 1944; Diven Medal 1959: for his tremendous contribution as an inspiring teacher, an accomplished engineer, and a selfless leader, who has spared no effort or energy in his personal and professional objective of water works advancement.*

Diven Medal

The John M. Diven Medal, awarded to the member whose services to the water utility field during the preceding year are deemed most outstanding, was presented to Lewis S. Finch. The citation follows:

LEWIS SPANN FINCH, Vice-President and Chief Engineer, Indianapolis Water Co.: *for his tireless and unselfish efforts in the successful launching and carrying forward of the Association's advancement program, and for his inauguration of the review of the Association's aims and objectives.*

Publications Award

The AWWA Publications Award, granted for the best paper published in the JOURNAL from October 1959 through September 1960, was con-

L. S. Finch

C. R. Ericksen

R. F. McCauley

W. R. Seeger

ferred upon Claud R. Erickson. The citation follows:

CLAUD ROBERT ERICKSON, Mechanical Engineer, Board of Water and Electric Light Commissioners, Lansing, Mich.: *for the paper "Submersible Water Well Pumps," published in the September 1960 issue of Journal AWWA* (Vol. 52, page 1145). *This paper provides a brief, readable, yet comprehensive survey of one of the newer tools of the water utility field, giving basic information on availability, operation, and cost for the guidance of the water works operator.*

Division Awards

Division Awards, granted for the best JOURNAL paper (October 1959–September 1960) in the field of interest of each of the four AWWA divisions, were presented to Robert F. McCauley, William R. Seeger, Jonathan L. Tuepker and Herbert O. Hartung, and Louis Koenig. The citations follow:

Distribution Division Award: ROBERT F. MCCAULEY, Associate Professor, Civil and Sanitary Engineering, Michigan State University, East Lansing, Mich.: *for his paper "Use of Polyphosphates for Developing Protective Coatings," published in the June 1960 issue of Journal AWWA* (Vol. 52, page 721). *This paper is valuable not only for its clear exposition of an important research project, but also for the fact that it introduces a practical means of protecting water distribution systems from the ravages of corrosion.*

J. L. Tuepker

H. O. Hartung

L. Koenig

Management Division Award: WILLIAM R. SEEGER, General Manager and Chief Engineer, Marin Municipal Water District, San Rafael, Calif.: *for his paper "Duties and Responsibilities of the Water Utility Manager," published in the September 1960 issue of Journal AWWA* (Vol. 52, page 1122). *This paper translates good management principles and the aims of the AWWA Advancement Program into the everyday activities and decisions of a water utility manager. In so doing, it makes a real contribution to the industry's effort to promote good utility management.*

Purification Division Award: JONATHAN L. TUEPKER, Superintendent of Purification, and HERBERT O. HARTUNG, Executive Vice-President, St. Louis County Water Company, University City, Mo.: *for their paper "Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction," published in the January 1960 issue of Journal AWWA* (Vol. 52, page 106). *This paper makes available to the field the results of some useful in-plant research on treatment procedures, thereby enriching not only the literature, but the art of water purification.*

Resources Division Award: LOUIS KOENIG, *Research Consultant, San* Antonio, Tex.: *for his paper "Survey and Analysis of Well Stimulation Performance," published in the March 1960 issue of Journal AWWA* (Vol. 52, page 333). *"This report fills a long-felt gap in the literature of the field, providing an evaluation of past experience with this procedure which indicates its more extensive application in the future.*

Safety Awards

The Wendell R. LaDue Safety Awards, granted to utilities for outstanding accomplishments in safety during a calendar year, were presented to the Stillwater (Minn.) Board of Water Commissioners; San Dimas-Charter Oak Domestic Water Co., San Dimas, Calif.; and the Pacific Gas & Electric Co. Water Systems, San Francisco, Calif. The citations follow:

Class 1: STILLWATER (Minn.) BOARD OF WATER COMMISSIONERS, Herbert S. Grove, General Manager: *for a 1960 record of 16,860 man-hours of work without a lost-time injury; no lost-time injuries for the last 10 years.*

Class 2: SAN DIMAS-CHARTER OAK DOMESTIC WATER CO., San Dimas, Calif. William P. Crum, Secretary-Manager: *for a perfect 1960 safety record with 19 employees working a total of 36,812 hours without a lost-time injury; no lost-time injuries since 1942.*

Class 3: PACIFIC GAS AND ELECTRIC CO. WATER SYSTEMS, San Francisco, Calif. John N. Spaulding, General Superintendent: *for a perfect 1960 safety record with 154 employees working a total of 308,000 hours without a lost-time injury; no lost-time injuries since 1956.*

Advancement Award

The All-AWWA Advancement Award is made annually to a water utility in recognition of outstanding achievement in the fields of community relations and professional advancement. The awardee is selected at the annual conference from among the winning entries in the local Section competitions held during the preceding year. Instituted in 1961, the first awardee was the GRIFFIN (GA.) WATER DEPT., L. A. Simonton, Supt.

Fuller Awards

The George Warren Fuller Awards were presented to 29 men whose sections had nominated them in the year beginning with the 1960 Annual Conference at Bal Harbour and ending with the opening of the 1961 Conference at Detroit. The awards—which are conferred for "Distinguished service in the water supply field and in commemoration of the sound engineering skill, the brilliant diplomatic talent, and the constructive leadership of men in the Association which characterized the life of George Warren Fuller"—went to the following men:

Alabama-Mississippi Section—HUGH LAMAR BURNS: *for his generous contributions in time and effort to the water works operators short course; his efficiency in handling local arrangements for meetings; his unsurpassed ability in selling AWWA; and for his progressive ideas and outstanding leadership in the section.*

Arizona Section—HARRY CLINTON BIGGLESTONE III: *for untiring assistance to the water systems of Arizona communities to meet fire-fighting standards and by expanding interest in the licensing of operators; and for his service on committees and in all offices of the section.*

California Section—JOHN CHRISTOPHER LUTHIN: *for his active participation in division and section affairs, as well as county and state affairs especially legislative; and for his comprehensive interest in the financing, planning, design, construction, and management of both large and small water works systems in California.*

Canadian Section—CHRISTOPHER GILLETTE RUSSELL ARMSTRONG: *for his public service in the water works field as a consulting engineer; for his exemplary service to the Canadian Section as chairman and director, and as an ever ready leader in water works programs.*

Chesapeake Section—BYRON BIRD: *in recognition of his contribution as a college professor to the advancement of water supply and sanitary engineering; for his outstanding work on studies for stream development for power, water supply, and flood control and as an engineer and administrator.*

Connecticut Section—WARREN ALBERT GENTNER: *for his able administration of the water division of a large metropolitan system through a period of major expansion and improvement, and for his many contributions to the water works profession through his services in water works associations.*

Florida Section—WALTER JOHN PARKS JR.: *for his more than thirty years of service to the water works industry and in the companion field of water pollution control; and for his continuing interest in the solution of the many environmental engineering problems encountered.*

Illinois Section—THURSTON E. LARSON: *for his diligent and tireless efforts on behalf of the water supply industry; his adept directing of in-service training and management programs; and his many years of unselfish devotion and the distinguished national honors he has brought to the section.*

Indiana Section—GEORGE GRANT FASSNACHT: *for his promotion of adequate and safe water supplies in Indiana; his dedication to improving water works practice; his tireless efforts in connection with the annual operators short school and certification program, the section's technical conferences, and the Hurty Award program.*

Iowa Section—HARRIS FORREST SEIDEL: *in recognition of the studies he has made and presented in the interest of the water works profession; and for the able assistance he has given the section on programs and committees.*

Kansas Section—HERBERT HENRY KANSTEINER: *in recognition of his exemplary career of nearly twenty-five years as manager of the Leavenworth water utility; his active participation and leadership in civic affairs; and his loyal service to the section as chairman and director.*

Kentucky-Tennessee Section—MARK BOONE WHITAKER: *for his devoted service to the section for many years and for his outstanding efforts in the promotion of an award-winning safety program in the Knoxville Bureau of Water.*

Michigan Section—WILLIAM CULLEN HIRN: *for his pioneering efforts in public health work; his untiring assistance to the field of water works operation; and his experienced counsel and advice to the water works profession over many years.*

Missouri Section—JOHN ARTHUR STRANG: *for his sustained interest in AWWA; for his many and varied services to the local section; for his active participation in the organizational membership drive and for his unselfish contribution to local arrangements at Association and section meetings.*

Montana Section—SAMUEL ROBERT YOUNG: *for his constructive leadership in finding and applying successful methods to cope with his community's especially difficult water treatment problems; and for his long and effective support of the section.*

Nebraska Section—MARTIN L. SIEVERS: *for his outstanding leadership in the design, improvement, and operation of the North Platte water system; and for the time, energy, and knowledge so freely and generously given to the Section and its membership.*

New England Section—WILLIAM BERNARD DUFFY: *for the advancement of his community water system; for his inspiring leadership in the affairs of the water works profession in New England; and for his interest and efforts in providing educational opportunities for young men in the water works industry.*

New Jersey Section—GEORGE ROBERT SHANKLIN: *for his wartime services in the water works facilities interchange program in northern New Jersey and his efforts in the solution of the long-range water supply problems of the state which led to the Spruce Run-Round Valley Reservoir project.*

New York Section—EGBERT DEFOREST CASE: *for his forty years of service to the water supply field, to the Association, and to the section as secretary, trustee, and director; and for his many contributions toward conservation of water throughout North and South America.*

North Carolina Section—E. M. JOHNSON: *for his years of service to the section as an officer and untiring worker, and for his devotion to the advancement of the municipal water works industry.*

North Central Section—HOWARD JAMES SOWDEN: *for distinguished service to the section as chairman and trustee; and for his leadership over the years in encouraging and promoting section membership and training and certification of water works personnel.*

Ohio Section—ERVIN FRANCIS LEIST: *for his sound administrative ability in the water utility field; devoted service in conservation and management of water resources; and his many years of service to the section on important committees, as trustee, and as chairman.*

Pacific Northwest Section—HARRY KENNETH ANDERSON: *for his sound long-range program of expansion of his city's water supply system; and for his valuable contributions toward the advancement of the programs of the Section.*

Pennsylvania Section—BAXTER FRENCH JOHNSON: *in recognition of many years of unselfish service on committees, and chairman of the section; and in further recognition of a lifetime of highly skilled professional effort resulting in quality water for his community, under varied and difficult conditions.*

Southeastern Section—JOHN RANDOLPH BETTIS: *in recognition of his many contributions to the section and to the water works short school; and in further recognition of his outstanding accomplishments in the field of water supply management and engineering.*

Southwest Section—HENRY WILKENS JR.: *in recognition of many years of distinguished service in the section, and for his untiring and enthusiastic promotion of the water works profession.*

Virginia Section—WILLARD WOODROW ANDERS: *for his conscientious and untiring efforts to advance the quality*

of service and product of the water works industry; and his continuous work in the affairs of the section and the Association.

West Virginia Section—WILLIAM SHAFER STAUB: *for his service to the water works field as an experienced engineer; his services to the section as chairman, director, and committee member; his cooperation in the biennial short courses; and his unselfish assistance to young sanitary engineers.*

Wisconsin Section—HARVEY EMIL WIRTH: *for outstanding work with state and section committees on water resources protection; on collection, compilation, and interpretation of basic water supply data; on presentation of section papers; and on administration of section affairs.*

Schedule of Conference Papers and Reports

MONDAY MORNING, June 5

General Session

AWWA Program.....C. F. Wertz
Why Banks Are Interested in the Water Industry.....Milton J. Redlich
Water Resources in the US.....*Senator* Robert S. Kerr

MONDAY AFTERNOON, June 5

Distribution-Management Divisions—Operations

What Is Adequacy in Water Utility Operations?—*Symposium*....*Led by* Gerald E. Arnold
Managerial Qualifications.....J. A. McCullough
Consumer Service.....M. D. Lubratovich, Earl H. Ruble
Rates.....Henry J. Graeser
Plant Facilities.....William R. Seeger
Accounting Practices.....Ralph L. Swingley
Engineering and Engineering Records.....E. Jerry Allen
Planning.....James W. MacLaren
Public Relations.....Johnie E. Williams

Purification Division—Processes

Experiences With Anthracite Sand Filters.....Walter R. Conley Jr.
Discussion.....Thomas R. Camp
The Nature of Organic Color in Water.....A. P. Black & Joseph Shapiro
Instrumentation and Automation.....Elwood H. Aldrich

TUESDAY MORNING, June 6

Open Session—Committee on Professional and Administrative Practice

Purification Division—Quality

Sand Filtration of Algae Suspension.....Jack A. Borchardt & Charles R. O'Melia
Removal of Algae by Microfilters.....A. E. Berry
Physiological and Health Aspects of Water Quality—*Committee Report*
Herbert O. Hartung
Water Quality Standard.....Elwood L. Bean

TUESDAY AFTERNOON, June 6

Open Session—Committee on Standardization

Water Resources Division—Quality

Water Resources and Problems of Michigan.....Norman Billings
Water Quality—*Joint Discussion*
Syndets and Pathogens.....Beverly W. Miller & Sister Mary Raphael
The Meaning of Water Quality.....S. Kenneth Love
Preventing Contamination of Water Resources.....Paul Bolton
Effects of Food and Paper Processing Waste Disposal Practices..Richard L. Woodward

WEDNESDAY MORNING, June 7

General Session

What AWWA Does for You.....John W. Cramer
Report by Committee on Aims and Objectives.....Fred A. Eidsness
Hydrologic Processes of Water, Snow, and Ice at High Altitude.....Fred A. Camp

WEDNESDAY AFTERNOON, June 7

Management Division—Quality

A Case History of Public Relations.....Leo Louis
Water Quality As It Affects Management—*Joint Discussion*
Attitude of USPHS.....Omar C. Hopkins
Surface Water in the Great Lakes Area.....Arthur Rynders
Ground Water in the Great Lakes Area.....Lynn M. Miller

Water Resources Division—Supply

Dual Water Supply for Seattle.....J. Ray Heath
Colorado River Study.....Floyd E. Dominy
Water Supply on the Moon.....Harry N. Lowe Jr.

THURSDAY MORNING, June 8

Water Utility Advancement Session

AWWA Advancement Program.....Eric F. Johnson
Guided Discussion of the Program.....*Led by* Robert F. Orth, John H. Murdoch, Samuel S. Baxter & Lewis S. Finch

Purification Division—Treatment

Progress in Saline Water Conversion—*Task Group Report*.....Rolf Eliassen
Operating Results in Four Filtration Plants in Detroit.....Albert M. Shannon
Committee and Task Group Reports

Distribution Division—Quality

Pressure Zoning and Maintenance of Distribution Systems.....E. S. Mamrelli
Right-of-Way Acquisition.....Henry J. Graeser
Maintaining Quality in Distribution Systems—*Joint Discussion*..*Led by* Frank E. Dolson, Oscar Gullans, H. C. Medbery, Benjamin C. Nesbit & H. J. Ongerth

THURSDAY AFTERNOON, June 8

Water Resources Division—Water Use

Diffusion of Radioactive Materials in Surface Streams.....R. C. Godfrey
Controlled Induced Recharge.....Morris Deutsch
Water Use in the US.....Kenneth A. MacKichan
Operating Experiences Under New Water Laws—*Task Group Report*..George E. Ferguson

Distribution Division—Design and Operation

Peak Demands in Resistance Areas.....Jerome B. Wolff
Putting Peak-Demand Data to Work in Operation and Design.....Holly A. Cornell
Demand Rates for Water Service.....W. L. Patterson

Social Calendar

Sunday	1:00 PM	Exhibit Open House	Cobo Hall Exhibit Area
	8:00 PM	Meet & Greet Night	Cobo Hall Ballroom
Monday	11:30 AM	Fashion Show & Luncheon	Rooster Tail Restaurant
	8:30 PM	Awards & Reception	Cobo Hall Ballroom
Tuesday	8:00 AM	Golf Tournament	Hillcrest C.C., Mt. Clemens
	1:00 PM	Cranbrook Tour	
	1:30 PM	Art Center Tour	
	7:30 PM	Carnival	Cobo Hall Arena
Wednesday	10:30 AM	Outdoor Barbecue & Tour	Greenfield Village
	Evening	No scheduled entertainment	
Thursday	10:00 AM	Sugar 'n' Spice Breakfast	Cobo Hall
	2:00 PM	Ladies Boat Trip	Leave foot of Woodward Ave.
	6:30 PM	Annual Banquet & Ball	Cobo Hall Ballroom

Exhibitors

Adams Pipe Repair Products
Allis-Chalmers Mfg. Co.
American Cast Iron Pipe Co.
American City Magazine
American Steel Foundries, Griffin Pipe Div.
American Well Works
Badger Meter Mfg. Co.
Baker, R. H., & Co.
B-I-F Industries
Brainard, F. S., & Co.
Buffalo Meter Co.
Byron Jackson Pumps
Calumet Meter Div., Worthington Corp.
Carus Chemical Co.
Centriline Corp.
Chain Belt Co.
Charles Machine Works
Chicago Bridge & Iron Co.
Clow, James B., & Sons
Darling Valve & Mfg. Co.
DeLaval Steam Turbine Co.
Donnelley, Reuben H., Corp., Water Works Engineering
Dorr-Oliver
Dresser Mfg. Div.
East Jordan Iron Works
Electro Rust-Proofing Corp.
Engineering News-Record
Fairbanks, Morse & Co.
Filtration Equipment Corp.
Fischer & Porter Co.
Fisher Research Lab.
Flexible
Ford Meter Box Co.
Foxboro Co.
Gamon Meter Div., Worthington Corp.
General Filter Co.
Glamorgan Pipe & Foundry Co.
Glenfield & Kennedy
Golden-Anderson Valve Specialty Co.
Graver Tank & Mfg. Co.
Hach Co.
Hagan Chemicals & Controls

Halliburton Co.
Hammarlund Automation Div.
Hanks, Fred W., Co.
Harco Corp.
Hays Mfg. Co.
Helige
Hersey-Sparling Meter Co.
Hupp Aviation Co.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.
Industrial Paint Co.
Inertol Co.
Infilco
Johns-Manville
Edward E. Johnson
Keasbey & Matison Co.
Koppers Co.
Layne & Bowler
Leopold, F. B., Co.
Link-Belt Co.
Lock Joint Pipe Co.
Ludlow Valve Mfg. Co.
Lynchburg Foundry Co.
McWane Cast Iron Pipe Co.
M & H Valve & Fittings Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
National Water Main Cleaning Co.
Neptune Meter Co.
Pan-American Health Organization
Pfaudler-Permutit
Philadelphia Gear Corp.
Pipe Linings
Pittsburgh-Des Moines Steel Co.
Pollard, Joseph G., Co.
Pratt, Henry, Co.
Preload Co.
Price Brothers Co.
Public Works Magazine
Puerto Rico Sewer & Aqueduct Authority
Roberts Filter Mfg. Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co.
Scranton Publishing Co., Water & Sewage Works
Smith, A. P., Mfg. Co.
Smith-Blair
Sparkler Mfg. Co.
Traverse City Iron Works
Trinity Valley Iron & Steel Co.
Tyler Pipe & Foundry Co.
US Bureau of Reclamation
US Geological Survey
US Public Health Service
United States Pipe & Foundry Co.
Visi-Meter
Wachs, E. H., Co.
Walker Process Equipment
Wallace & Tiernan Inc.
Water Pollution Control Federation
Welsbach Corp.
Wheeler, C. H., Mfg. Co.
Wheeler Mfg. Corp.
Willamette Iron & Steel Co.
Wood, R. D., Co.

Monthly Water Bond Interest Costs and Sales

A report of the Chief, Basic Data Branch, Div. of Water Supply & Pollution Control, US Public Health Service, Washington, D.C.

Month	1960–61 Net Interest Cost—*per cent*		Total Bond Sales—*$1,000,000*		
	General Obligation Bonds	Revenue Bonds	1960–61	1959–60	1958–59
Aug.	3.34	4.02	48.4	25.5	37.7
Sep.	3.82	3.75	18.8	16.6	14.3
Oct.	3.64	3.85	21.0	68.4	60.8
Nov.	3.36	3.86	18.4	36.3	42.5
Dec.	3.55	4.20	77.3	18.4	11.5
Jan.	3.88	3.70	37.8	21.2	28.3
Feb.	3.41	3.71	19.4	41.7	62.1
Mar.	3.47	3.48	102.8	19.5	57.0
Apr.	3.85	3.81	16.2	38.2	44.4
May	3.36	3.62	48.9	49.9	105.5
Jun.	4.09	3.86	80.4	111.4	50.3
Jul.	3.66	4.50	8.8	33.1	17.3
Total			498.3	480.2	531.7

Papers Scheduled at 1961 Section Meetings

THERE follows a summary listing of papers scheduled for presentation at 1961 section meetings. The dates of the section meetings from 1957 to 1961 and the locations for 1961 are listed on page 1582. Section officers who were elected at meetings held during 1961 are listed on page 2 P&R in the front of this issue. The programs are listed alphabetically by sections, without regard to the date of presentation.

Alabama-Mississippi Section—Oct. 8–11, 1961

Address of Welcome.....*Mayor* Daniel B. Guice
Trials and Tribulations of a Water Works Man.....Tip H. Allen
Report from National Director.....Jess L. Haley
Civil Defense and Water Protection.....Robert L. Crook
Contamination Control—Panel Discussion.....*Led by* Tom Robinson, W. H. Gilmore, John E. Trigg & J. E. Johnston
New Developments in Pipe and Fittings—Panel Discussion.....*Led by* J. E. Jagger
Asbestos-Cement.....C. C. Clubb
Cast Iron.....Donald W. Harrington
Concrete.....John G. Hendrickson Jr.
Cooper.....A. I. Heim
Steel & Plastic.....F. H. Ramage
Rescue Breathing.....Tom Bailey
Pertinent Activities in the Water Industry.....Raymond J. Faust
Your Home Town Water Works Problems.....C. C. Williams
Problems in Water Research Investigations.....W. H. Robinson
Master Metering.....C. A. Parnow
Are You Going To Drink That?.....Robert G. Zilly
The Water Works Man in His Community.....*Mayor* John D. Holland

Arizona Section—Apr. 20–22, 1961

Address of Welcome.....Boyd H. Gibbons, Jr.
Phoenix Bond Construction Program, 1957.....Pete Lallande
The Life and Near Death of Well 72.....Glen Ehrich
Electrodialysis—Its Application in Arizona.....Richard Fiedler
New Concepts in Digester Sludge Mixing and Floating Covers.....G. E. Hauer
Maintenance of Water Production Facilities.....Clarence Pollard
Corrosion of Water Systems Equipment.....Loring Tabor
River Under the Desert.....Gordon Marshall
A Biological Study of the Sewage Lagoon of Sanitary District No. 1 of Pima County, Arizona.....Jack Hensley
Water Quality Criteria.....Dr. John Klock
Potential Application of Solar Energy in the Water and Sewage Fields.....Levi F. Yissar
Panel Discussion—School and Certification.....Roswell Jones, L. O. Henry & Dr. Karl Hirlinger

California Section—Apr. 13–14, 1961

Address of Welcome.....*Mayor* E. L. Abbott
The Influence You Exert On Your Community.....Duncan A. Blackburn

Telemetering For Small Utilities.....Alfred W. Jorgensen
The Whittier Narrows Water Reclamation Plant.....John D. Parkhurst
The Work of the Center For Study of Democratic Institutions.....Stanley K. Sheinbaum
Collection Procedures and Delinquent Accounts—Panel Discussion.....
Led by Patrick J. Maloney, Camille A. Garnier, Robert B. Hunter, Kenneth D. McCloskey, Ralph B. Lindberg & Emanuel Becker

California Section—Oct. 24–27, 1961

Address of Welcome.....*Mayor* James B. McKinney
Water Developments in California—The State's Role.....William F. Warne
Improved Water Service.....John W. Cramer
Sacramento Plans Ahead.....Ray W. Jones
Recent Developments in East Coast—New England Water Works Practices..Rolf Eliassen
Controversies Over Water Rights.....*Led by* Samuel B. Morris
State Water Rights.....Burnham Enersen
The National Interest in Water Resources.....Ramsey Clark
Ground Water Management Is Everybody's Business.....James H. Krieger
Ground Water Basin Management.....Rex Goodcell
County-of-Origin Taxation of Water Rights.....George Huberty
The Water Exporter's Point of View Regarding Taxation of Water Rights.....
Orville I. Wright
Safety at the Management Level.....Chandler A. Laughlin
Application of Tabulating Equipment to Medium-Size Utility Billing....Gerald W. Peasley
Employee Attitudes and What To Do With Them.....James Harrington Jr.
Behavior and Evaluation of Microstraining for the Lytle Creek Supply.....
Ralf Carter, Henry J. Ongerth & Sam H. Woody II
Manipulative Improvements on the Membrane Filter Technique.....J. J. Connors
Diatomaceous Earth Filtration.....G. R. Bell
Water Supply—Domestic Service and Fire Protection.....Thomas M. Morgan
Why Survey Gate Valves?.....Kenneth L. Wilkerson
Gas Engines for Economical Pumping Operation.....J. E. Curtis
Hydrologic Processes of Water, Snow, and Ice at High Altitude.....Fred A. Camp
Loss in Water Main Capacity.....E. S. Mamrelli & Lee Streicher
Motion Pictures: White Gold; Water for the Valleys; 1960 Mid-Pacific Conference

Canadian Section—Jun. 1–3, 1961

Address of Welcome.....*Mayor* M. J. Patrick
Protection Against Cold Weather Effects on Water Mains, and Conditions Related Thereto—Discussion.....*Led by* R. Harrison
Water Fluoridation—Present Status.....A. E. Berry
Modern Practice in Water Chlorination.....D. H. Matheson & A. V. Forde
Modern Accounting Practices for Canadian Water Works.....Paul Hickey
Objectives in Water Works Administration—Discussion.....*Led by* C. C. Calder
The Union Water Filtration Plant.....C. G. R. Armstrong
The Windsor Water Works System.....G. H. Strickland
Design and Operating Features of an Unattended, Automatic Pumping Station at Winnipeg
F. Gordon Denson
Legal Problems in Water Works Administration.....Harry Landis
Water Use Regulations—The Need of an Effective Program....A. K. Watt & K. Symons
Trend in Water Purification Processes.....N. G. McDonald & R. A. G. Simmons

Canadian Section, Maritime Branch—Oct. 2–3, 1961

Address of Welcome.....*Mayor* S. H. Rideout
General Water Works Problems—Discussion.....*Led by* J. R. Richards

Treatment for Maritime Waters.....W. K. Sharpe
Design Problems in a Small Water Plant & System.....W. H. Crandall
Federal Assistance in Municipal Sewerage Construction.....C. F. Emms
Meters in the Water Industry—Panel Discussion.....*Led by* A. E. Hanson
Advantages and Disadvantages.....*Colonel* P. C. Ahern
Selection, Operation and Maintenance.....H. C. Greer
Records, Rates and Routes.....J. W. Curchill
Flow Measurements in Water Distribution Systems and Their Application for Efficient Operation and Design.....C. J. Knoener
Administration and Finances—Discussion.....*Led by* C. J. McLellan
Sewage and Sanitation Problems—Discussion.....*Led by* W. L. Barrett
The Montreal Water Works System.....Lucien L'Allier

Chesapeake Section—November 1–3, 1961

Address of Welcome.....*Mayor* J. Harold Grady
Potomac River Resources Development.....*Colonel* Warren R. Johnson
Metamorphosis of the Montebello Tunnel.....Ralph E. Marquiss
Removal of Syndets with Activated Carbon.....E. A. Sigworth
Relocation of Water Utilities.....Jerome B. Wolff & Robert J. McLeod
Water Meter Replacement Program.....Milton R. Vollmer & James H. Lee
Modern Waterworks Developments—Panel Discussion
Valveless Filters.....D. M. McKee
In-Line Pumping.....D. F. Burrell
Higgins Contactor.....Irvin R. Higgins
Zeta Potentials.....Arden Sirles
Water Rate Regulation.....Hugh Hunter
Water Rates.....Ernest C. North
What's New on the Waterfront.....George E. Ferguson
McIlroy Analyzer Experiences.....E. Pierce Lineweaver, Jr.
New Water Supply for Frederick, Md.....R. A. Whiteford
In-Service Training of Municipal Engineering Employees.....T. M. Mouring

Connecticut Section—Sep. 28, 1961

What AWWA Does For You.....John W. Cramer
Administration of Water Resources Statutes in Connecticut
John J. Curry, Merwin Hupfer & Charles J. Pelletier
International Water Supply Conference.....Richard V. Ford

Florida Section—Oct. 29–Nov. 1, 1961

Address of Welcome.....*Mayor* Robert S. Carr
Sanitary Engineering in Florida—Past, Present and Future.....David B. Lee
Automatic Control of Water Treatment Plants.....John V. Miner, Jr.
Real Estate Phase of Your Expansion Program.....S. M. Heasley
Automatic Valveless Gravity Filter.....George H. Dacy
Application of the 1961 Drinking Water Standards to Florida Conditions—Panel Discussion
Led by F. W. Gilcreas
Chemical Analyses.....A. P. Black
Bacteriological Analyses.....Hugh F. Butner
Administration by the Florida State Board of Health.....John B. Miller
Report of the Florida Geological Survey.....*Led by* Robert O. Vernon
Report of the U. S. Geological Survey.....A. O. Patterson
Report of the Air Pollution Control Commission.....E. R. Hendrickson
Motion Picture: How Our Town Saved the River

Illinois Section—Mar. 22–24, 1961

Address of Welcome.....*Commissioner* James W. Jardine
Public Relations in a Water Utility.....Wallace T. Miller
Experience With Paint and Other Coatings for Water Works Structures—Panel Discussion.....*Led by* Oscar Gullans, Harry D. Harman, Peter M. Johnson, D. W. Christoffer & Gustav A. Ronsen
An Unusual In-Line Horizontal Submersible Booster Pump Installation for Distribution Systems.....George Petri
Natural Gas Fuel as a Prime Mover for Deep-Well Pumping.....Lloyd Yates
Economics—Detergent Consumption and Water Hardness.....Lloyd DeBoer
Pollution Problems, Function of the Federal Government.....Gordon E. McCallum
Functions of the State Government in Controlling Pollution of Water Supplies..... Richard Nelle
National Water Quality Network.....S. R. Weibel
Illinois Water Quality Network.....C. W. Klassen
Progress Report—Great Lakes and Illinois River Basin Pollution Studies..William Q. Kehr
Disposal of Lime Sludge—Panel Discussion
Lagoon Disposal.....Louis R. Howson
Filtration Method.....Gerald L. Davis
Centrifugal Method.....E. C. Cardwell
Laboratory and Field Studies on the Treatment of Iron-Bearing Waters....J. M. Longley, F. S. Engelbrecht & G. E. Margrave
Well Supplies.....Jim Moran, Jason N. Daykin & Lawrence A. Parker
Surface Supplies.....G. L. Watson, John H. Blesse & Rex Gaston
Pumps.....M. P. Schneller
Gravity Filters.....O. J. Smith
Maintenance Equipment for Distribution Systems.....H. S. Merz
Wells.....R. W. Brooks
Pressure Filters.....Doyle Adkins
Zeolite Softeners.....Clifford Fore
Motion Pictures: Priceless Water; New Power From the Niagara; How Our Town Saved the River; Seconds for Survival

Indiana Section—Feb. 1–3, 1961

Address of Welcome.....J. B. Wilson
Peak Loads, Storage and Distribution Problems.....Ed Farmer
Discussion.....Thurman Shoults & John McCauslin
The Need for Distribution Systems Maps and Records.....Clyde C. Leeke
Organizing for Maps and Records.....M. C. Stout
Patterns of Informal Communications Within Organizations—Panel Discussion..... *Led by* William Haeberle, Eaton H. Conant, Fremont A. Schull
Treatment and Control Problems—Including Effects of Widespread Use of Detergents.... E. A. Sigworth
Discussion.....Lawrence J. Killian & Thomas Moore
Ground-Water Contamination—The Problem in Indiana.....Donald G. Jordan
Labor Relations in Water Works.....Fred Witney
What Do You Want AWWA to Do For You?.....John W. Cramer
How Are Your Public Relations?—Responsibilities of Meter Readers and Their Relations With Customers.....Loren Mellendorf
Collection Policies.....Paul E. Clark
Motion Pictures: 1960 Speedway 500 Mile Auto Race

Intermountain Section—Oct. 5–6, 1961

Address of Welcome.....*Commissioner* Vernon Riddle
Ground Disposal of Radioactive Waste.....Bruce L. Schmalz
Minerals in Water.....Howard M. Hurst
Use of Coagulant Aids in Water Treatment.....R. M. Tarr
Insulating Couplings and Bushings—Type and Use.....William J. Speir
Water Reports Required by State Agencies.....Vaughn Anderson & Earl W. Chapman
Ground Water and Surface Water—a Single Resource.....M. J. Mundorff
Type and Use of Water Metering Devices for Main-Line Service.....Edward F. Morey
Pump Maintenance and Operation.....E. J. Watts
Retardation of Reservoir Evaporation by Use of Chemicals.....Quentin L. Florey

Iowa Section—October 18–20, 1961

Address of Welcome.....*Mayor* James J. Meaghan
The Coralville Dam and Its Effect on Iowa River Water Quality.....Marcus Powell
Water & Sewerage Technical School.....Lloyd Caughran
Operating the Cedar Rapids Water Treatment Plant, Summer, 1961.....Arnold Cherry
Mining Our Natural Resource—Water.....Charles Brown
Waterworks Maintenance—Panel Discussion.....*Led by* Harley Boeke
  Water Distribution System.....R. A. Wilford
  Water Tanks—Cathodic Protection.....Melvin W. Williams
  Concrete.....D. H. Comann
  Paints—Under Water.....John Rohwedder
  Paints—Above Water.....Fletcher Shanks
The Superintendent, the Engineer, and the Water System.....Sherman Smith
Taiwan Today—Water, Tea, or Rice Wine.....Harris F. Seidel

Kansas Section—Apr. 12–14, 1961

Address of Welcome.....*Mayor* Jerry Stremel
Publications.....Madison West
Background and Development of New Federation Policy on Stream Pollution.....
Mark D. Hollis
Today's Needs in the Water Supply Industry.....John W. Cramer
Resume of Recent Legislative Action on Questions of State Water Policy..Robert L. Smith
Operation and Maintenance as Related to Revenue Financing of Water and Sewer Utilities
Ray Reed & Fred Littooy
Water Works Improvements—Panel Discussion.....
Raymond W. Bruggeman & Ellsworth L. E. Zahm
Mobile Radio for the Water Utility.....Robert Clendenin
Current Efforts of AWWA to Increase The Services of the Association to You.....
John W. Cramer
Cathodic Protection for Water Works Structures.....Raymond H. McLeod, Jr.
Some Aspects of Water Plant Design, Operation, and Maintenance.....M. E. Rogers
Water Main Cleaning—Panel Discussion.....Jack R. Kelsey & Thomas E. Deaton
Interpretation of Project Plans.....Elmer N. Pearse
Digester Heating—Panel Discussion.....*Led by* Leland Talbot,
Henry W. Nedeau, Jerry Hatcher & Leonard Beyer
Protective Paints for Sewer Structures.....Thomas J. Canty
Current Development in the Water Pollution Field.....Mark D. Hollis
Gas Recirculation.....Richard E. Day
Status of Retirement Program for Public Employees.....F. D. Diehl
Motion Pictures: The Voice of Your Business; George Washington's River; Water Conditioning

Kentucky-Tennessee Section—Sep. 10–13, 1961

Address of Welcome.....Neil Dalton
Operator Licensing and Laboratory Certification—Discussion.....
Julian R. Fleming & Nick G. Johnson
Joint Water and Sewer Billing With Sales Tax—Discussion.....B. E. Bayne,
Harold Mount & Philip Bell, Jr.
The Public Service Commission and Water and Sewer Utilities—Discussion.....
E. C. O'Rear, Stanley J. White & Alfred Le Feber
Taste and Odor—Panel Discussion.....Thomas E. Maloney & M. B. Ettinger
Standpoint of Plant Operation—Discussion.....William G. Green,
William L. Williams & John J. Quinn
Laboratory in Plant Operation—Discussion.....Dan Enright & W. W. Smithers
Water Quality—Panel Discussion.....Leo Weaver,
George W. Whetstone, William M. Clay & William Klein

Missouri Section—Oct. 1–3, 1961

Address of Welcome.....*Mayor* David Scott
Mandatory Licensing of Plant Operators.....W. G. Riddle
Ductile Iron Pipe.....J. B. Hill
Modern Distribution System Practices—Panel Discussion
Valve Inserting Machines.....R. L. Jolly
Harnessing and Blocking.....L. J. Lukrofka
Power Installation of Corporation Cocks.....E. O. Norman
Use of Rotary-Type Valves in Distribution Systems.....J. H. Whisler
Steel Storage Tanks.....L. H. Fabian
New Federal Legislation Relating to Water Conservation and Sewage Disposal..H. C. Clare
Effects of Sewage Lagoons on Water Supplies.....T. R. Beveridge
What Makes a Sound Bond Issue?.....C. B. Kaiser
Protective Coatings.....T. F. Stanley
Performance Criteria.....H. O. Hartung
Diagnosis of Pump Problems and Selection.....D. L. Gallagher
Economics of Extending Water Mains.....M. P. Hatcher

Montana Section—Apr. 6–8, 1961

Address of Welcome.....*Mayor* Wanna Thompson
1961 Legislative Session.....Alfred F. Klingler
Water Quality Criteria—Classification of Montana Streams.....C. W. Brinck
Role of Steel in Modern Water and Pollution Control Systems.....J. S. Leffler
Round Table.....*Led by* Fred Taylor
Challenges of the Water Works Industry.....Raymond J. Faust
Public Relations.....George O'Connor
Civilian Defense with Regard to Water and Sewage Systems.....*Major* Robert A. Keyes
Motion Pictures: An American Landmark; New Power from Niagara; How Our Town Saved the River

Nebraska Section—April 19–20, 1961

Address of Welcome.....*Mayor* Pat Boyles
New Water Plant Problems and Solutions.....Walter H. Andrews & George H. Allen
Water Distribution Repairs—Panel Discussion.....*Led by* Joseph J. Rossbach
City Communications.....Emil Wagner
The Economics of Underground Distribution.....Ronald J. Locher & Willard H. Reuss
Red Water.....Kenneth E. Moehrl
Motion Picture: Seconds for Survival

New Jersey Section—Oct. 25–28, 1961

Address of Welcome.....Peter E. Pallo
Aims and Objectives.....Raymond J. Faust
Management and Engineering Seminars—Near and Far East .....Oscar A. Newquist
Plastic Pipe.....George H. Reed
Remote Control Supervisory Systems.....Arnold S. Giannetti
Peculiarities of Water Supply—New Jersey Turnpike Service Areas.....Robert C. Moore
Responsibility Accounting Can Make You A Better Supervisor.....Harvey D. Goff
Saline Water.....Charles F. MacGowan
New Water Quality Standards.....Malcolm C. Hope
Radioactive Surveys—New Jersey Surface Waters.....William H. Aaroe
Community Relations Aids for Water Superintendents..James B. Corey & Eric F. Johnson
Well Inspections by TV.....Robert Obermann
What is Ground Water?.....Jack B. Graham
Natural and Artificial Discharge of Ground Water At a Site on The Mullica River in the Wharton Tract, Southern New Jersey.....S. M. Lang & E. C. Rhodehamel
Hydrologic Role Of The Great Swamp And Other Marsh Land In The Upper Passaic River Basin.....John Vecchioli & Harold E. Gill
Tracing The Continuity Of Pleistocene Aquifers in Northern New Jersey By Geophysical And Hydraulic Methods.....Harold E. Gill & John Vecchioli
Delaware River Compact.....James Kerney, Jr.
New Surface Water Studies.....John E. McCall
Round Valley Report.....Paul J. Rigo
Spruce Run Report.....Arnott King
The Aquatic Life of a River.....Ruth Patrick
Round Table Discussion.....*Led by* Arthur P. McConville
Motion Pictures: How Our Town Saved The River; George Washington's River; Deep Waters

New York Section—Apr. 10–11, 1961

Address of Welcome.....*Mayor* Frank A. Sedita
Water Works School—Telemetering in Water Utilities.....*Led by* George E. Symons
Diatomaceous Earth Filtration—Discussion
Diatomaceous Earth Pressure Filtration.....William Heymann
Diatomaceous Earth Vacuum Filtration.....Henry Armbrust
Coagulant Coated Diatomaceous Earth Filter Aids and their Use in Potable Water Filtration.....G. R. Bell
Purification of Water Containing Synthetic Detergents, Herbicides and Insecticides.....E. A. Sigworth
Modern Billing Machine Practices for Water Utilities.....P. L. Foley
Onondaga County Water Supply.....Thomas Dyer
Round Table Conference.....*Led by* Harold F. Rock
Motion Pictures: The Diatomite Process; The Prosperity of Water

New York Section—Sep. 13–14, 1961

Water Works School Water Supply versus Underwriters.....*Led by* Harold F. Rock
The Rating of Water Supplies.....G. C. Anderson & Richard H. Chamberlain
Round Table.....*Led by* Edward M. Griffin
Plastic Pipe is Here to Stay.....James Luby
Water Works Practices and Problems in the Middle and Far East.....John G. Copley
Cast Iron Flexible Joint For River Crossings And Unstable Soil Conditions..W. K. Stearns
Application Of Variable Speeds Pumps For Efficiency and Controllability..Adam W. Kubik

North Carolina Section—Nov. 13–15, 1961

The Asheville Water System.....P. Greer Johnson
Pollution Abatement in the French Broad River Basin.....W. E. Long Jr.
The University of North Carolina Galvanic Oxygen Analyzer.....
K. H. Mancy & W. M. Westgarth
Covered Trickling Filters.....John L. Brown Jr.
Coagulant and Filter Aids—Panel Discussion.....*Led by* Wade G. Brown,
Jesse M. Cohen, H. D. Fesperman & Max Sawyer
Specifications—Panel Discussion.....*Led by General* J. R. Townsend
Municipalities.....*General* J. R. Townsend
Presenting Legal Aspects.....G. H. Abplanalp
Consulting Engineers.....George S. Rawlins
General Contractor..... W. F. Lee
Suppliers.....Charles V. Roberts
Role of Saline-Water Conversion in Water Supply.....J. C. Lamb
River Basin Development.....*Colonel* Harry E. Brown
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Purchasing for Water Utilities.....R. A. Berry
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Section Membership at Time of, and Total Attendance at, Section Meetings—1957–61

Section	1957		1958		1959		1960		1961	
	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance
Alabama-Mississippi	224	307	235	279	253	225	253	318	252	305*
Arizona	84	234	104	170	107	260	105	280	111	296*
California§	1,451	1,225	1,601	1,710	1,728	470#	1,724	1,445	1,747	1,319*
Canadian§	708	500	730	922	753	910	762	778	780	737
Chesapeake	288	228	306	157	310	230	310	236	—	—
Connecticut	††	††	††	††	††	††	102	96	120	85*
Cuban	62	‖	58	†	56	43	49	†	11	†
Florida	361	399	385	460	377	324	420	497	430	—
Illinois	589	474	650	509	707	811	712	604	687	491*
Indiana	478	499	525	602	538	429	513	510	495	400*
Intermountain	**	**	76	107	107	108	114	136	106	—
Iowa	181	282	189	289	208	277	215	302	230	—
Kansas	239	217	259	228	257	223	245	197	238	246*
Kentucky-Tennessee	252	317	268	368	268	344	257	345	250	373
Michigan	471	341	505	335	528	408	530	417	539	‡
Missouri	238	306	246	289	251	320	231	310	248	300
Montana	61	132	64	154	63	115	63	117	72	160*
Nebraska	109	156	107	63	104	143	104	172	115	172
New England	248	†	258	†	271	†	184	†	187	†
New Jersey	505	336	531	370	543	381	554	406	586	428*
New York§	882	458	884	505	923	540	937	542	955	560
North Carolina	224	305	215	‡‡	203	335	199	326	—	—
North Central	278	177	260	199	255	181	262	202	276	235*
Ohio	508	281	517	334	522	378	504	416	506	—
Pacific Northwest	507	358	500	398	481	391	473	562	474	560*
Pennsylvania	558	235	560	251	566	258	586	311	582	266*
Rocky Mountain	237	152	205	166	209	140	213	260	228	291*
South Dakota	††	††	††	††	††	††	46	144	51	157
Southeastern	300	335	326	446	315	367	320	376	318	387
Southwest	1,133	784	1,113	‡	1,090	1,062	1,162	810	1,176	930*
Virginia	213	241	216	216	214	228	215	237	223	250*
West Virginia	105	195	112	201	121	194	119	207	121	186*
Wisconsin	206	340	216	319	220	324	304	381	359	281*

* Paid attendance, given for purposes of Henshaw Cup competition.
† No regular meeting scheduled. Membership given as of dates of conferences.
‡ Regular meeting canceled. Business meeting held at annual conference.
§ Only one of section's meetings recorded here.
‖ Meeting canceled.
A one-day meeting, because the annual conference was held in San Francisco.
** Section organized in 1958.
†† Section organized in 1960.
‡‡ No record of attendance.

Section Meetings—1957–1961

Section	*1957*	*1958*	*1959*	*1960*	*1961*	*Meeting Place—1961*
Alabama-Mississippi	Oct. 20–23	Sep. 28–Oct. 1	Oct. 18–21	Oct. 9–12	Oct. 8–11	Biloxi, Miss.
Arizona	Apr. 4–6	May 15–17	Apr. 16–18	Apr. 28–30	Apr. 20–22	Apache Junction, Ariz.
California	Apr. 26*			Apr. 22*	Apr. 14*	Santa Barbara, Calif.
	Oct. 29–Nov. 1	Oct. 28–31	Oct. 30	Oct. 25–27	Oct. 25–27	Sacramento, Calif.
Canadian	Jun. 17–19	Jun. 1–4	May 3–6	Apr. 24–27	Jun. 1–3	Windsor, Ont.
	Oct. 17–18†	Oct. 1–3†	Sep. 9–11†	Sep. 28–30†	Oct. 2–3†	Moncton, N. B.
Chesapeake	Oct. 30–Nov. 1	Oct. 29–31	Oct. 7–9	Nov. 2–4	Nov. 1–3	Baltimore, Md.
Connecticut				Oct. 6	Sep. 28	Newington, Conn.
Cuban	‡		Nov. 19–21	‡		
Florida	Nov. 10–13	Oct. 19–22	Nov. 15–19	Nov. 13–16	Oct. 29–Nov. 1	Orlando, Fla.
Illinois	Mar. 20–22	Mar. 26–28	Mar. 11–13	Mar. 16–18	Mar. 22–24	Chicago, Ill.
Indiana	Feb. 6–8	Feb. 5–7	Feb. 4–6	Feb. 3–5	Feb. 1–3	Indianapolis, Ind.
Intermountain		Nov. 6–7	Oct. 8–9	Oct. 6–7	Oct. 5–6	Twin Falls, Idaho
Iowa	Oct. 16–18	Oct. 15–17	Oct. 14–16	Oct. 19–21	Oct. 18–20	Cedar Rapids, Iowa
Kansas	Apr. 10–12	Mar. 12–14	Apr. 22–24	Apr. 20–22	Apr. 12–14	Hutchinson, Kan.
Kentucky-Tennessee	Sep. 23–25	Sep. 22–24	Sep. 14–16	Sep. 12–14	Sep. 11–13	Louisville, Ky.
Michigan	Sep. 25–27	Sep. 8–10	Sep. 23–25	Sep. 21–23		
Missouri	Sep. 29–Oct. 1	Sep. 28–30	Sep. 27–29	Sep. 25–27	Oct. 1–3	Springfield, Mo.
Montana	Apr. 4–6	Mar. 20–22	Apr. 9–11	Apr. 28–30	Apr. 6–8	Helena, Mont.
Nebraska	Apr. 24–26	Apr. 16–18	Apr. 15–17	Apr. 20–22	Apr. 19–21	Lincoln, Neb.
New England						
New Jersey	Oct. 24–26	Oct. 23–25	Oct. 22–24	Oct. 20–22	Oct. 25–28	Atlantic City, N.J.
New York	Apr. 10–12	Mar. 26–28	Apr. 8–10	Apr. 5–7	Apr. 11–13	Buffalo, N.Y.
	Sep. 11–13	Sep. 10–12	Sep. 16–18	Sep. 14–16	Sep. 13–14	Saranac Lake, N.Y.
North Carolina	Nov. 11–13	Nov. 10–12	Nov. 9–11	Nov. 9–11	Nov. 13–15	Asheville, N.C.
North Central	Sep. 25–27	Sep. 24–26	Sep. 16–18	Sep. 21–23	Sep. 13–15	Minneapolis, Minn.
Ohio	Sep. 18–20	Sep. 17–19	Oct. 28–30	Oct. 26–28	Oct. 25–27	Toledo, Ohio
Pacific Northwest	May 2–4	May 15–17	Apr. 23–25	May 4–6	Apr. 26–29	Victoria, B.C.
Pennsylvania	Jun. 12–14	Jun. 25–27	Jun. 3–5	Jun. 14–17	Jun. 20–22	Wernersville, Pa.
Rocky Mountain	Sep. 23–25	Sep. 15–17	Sep. 8–10	Oct. 24–27	Oct. 2–4	Taos, N.M.
South Dakota				Sep. 7–9	Sep. 20–22	Rapid City, S.D.
Southeastern	Mar. 17–19	Mar. 23–25	Apr. 5–8	Mar. 20–23	Apr. 23–26	Greenville, S.C.
Southwest	Oct. 13–16		Oct. 18–21	Oct. 16–19	Oct. 15–18	San Antonio, Tex.
Virginia	Nov. 6–8	Nov. 5–7	Nov. 4–6	Sep. 14–16	Oct. 4–6	Roanoke, Va.
West Virginia	Oct. 23–24	Oct. 23–24	Oct. 28–29	Mar. 24–25	Apr. 5–6	Bluefield, W.Va.
Wisconsin	Sep. 4–6	Sep. 17–19	Sep. 9–11	Sep. 28–30	Sep. 27–29	Milwaukee, Wis.

* Regional meetings. † Maritime Branch. ‡ Meeting canceled.

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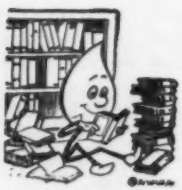

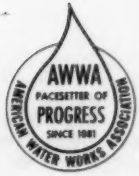

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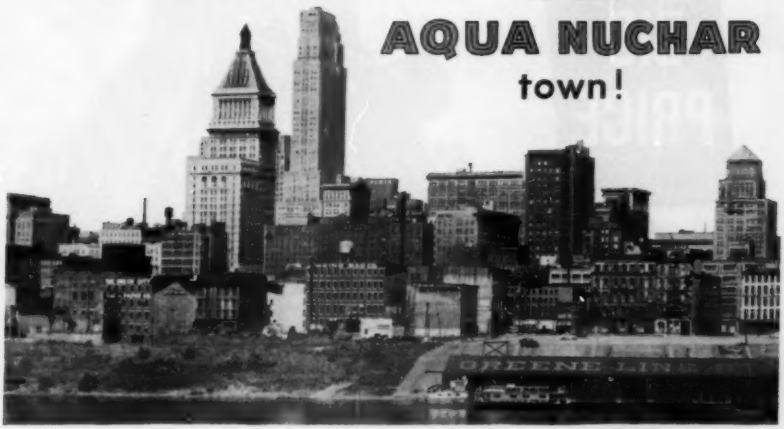
why would a camel walk a mile for a drink at the Municipal Zoo?

because Cincinnati is an AQUA NUCHAR town!



The song calls the river from which Cincinnati draws its drinking water the "Beautiful Ohio". No mention is made of palatability, but folks there like its consistent good taste nonetheless.

That's because Cincinnati's municipal water plant runs daily threshold odor tests and applies AQUA NUCHAR Activated Carbon in controlled dosages to eliminate any unpleasant taste-and-odor variations detected.

Treatment with AQUA NUCHAR is the most effective method for adsorbing tastes and odors due to algae, decaying vegetation, trade wastes and other causes. AQUA NUCHAR is economical, too, since average dosages of only a few ppm are sufficient.

Moral: don't let your customers go even one day without good-tasting water. It's so easy to let our technical staff survey your plant and make recommendations that will assure you of consistent palatability.

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When you open the water meter bids...

ADD UP THE TRUE TOTAL

BID PRICE

+

OTHER COSTS:

Revenue losses

Repairs

Obsolescence
(if any)

New Trident Model 60 Sealed Meter

THEN make the best buy...

A water meter should be a lifetime purchase. Its price tag gives only *part* of its cost. Look instead for *true annual costs:*

First, think of revenue loss. A meter returns 12 to 20 times its price before its first check-up. A slight slip in accuracy loses more money than you "save" in a low bid.

Secondly, meters must be tested regularly. One that checks OK *without* repairs obviously is worth more. In the long run, the meter that is *easiest* to repair is also worth more.

Finally, with most meters you must add obsolescence. But not with Trident. A Trident constantly modernizes itself. All design improvements are made to fit older Tridents too; you get them *automatically* as you insert replacement parts.

Trident meters are designed not for low bid but for low true annual cost. That's why Trident is always your "best buy."

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Merry Christmas

Free admission time is here again for P&R, and those who must, after a year of anonymity, now be admitted are the 72 senders of the stuff of which P&R is made—the P&R editorial stuff staff, no less.

Many of these hitherto unthanked innominates will be surprised, if not dismayed, to find themselves admissible, having made their contributions utterly unaware of the consequences, but most of those listed enlisted, and their degrees of privity can best be judged by their designated powers. Lest our motive be misapprehended, however, we hasten to point out that, in hereby desecrefying for the fourteenth time the purpose of, as well as the rolls of, P&R's ordinarily unadmitted Editors Anonymous, we seek to honor, not to blame them. And we ascribe this annual weakening of our resolve to protect, if not to conceal, their identity as an attack of Christmas spirit.

Under attack, then, we admit that those listed below provided our wherewithal not only for 1961, but for as many years as their "powers" indicate. And most attacktively we would commend to Christmas consideration Ellsworth Filby, Harry Jordan, Joe Wafer, and Syd Wilson for full fourteen years of anonymosity. Meanwhile, not only for his years, but for his "Years Ago," Russ Johnson certainly deserves a better fate. All of which is to suggest that the least you can do, in the spirit of the season, is to join us in wishing a Merry Christmas to our

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and we'll promise ourself not to inquire too closely into what was meant by your Happy New Year.

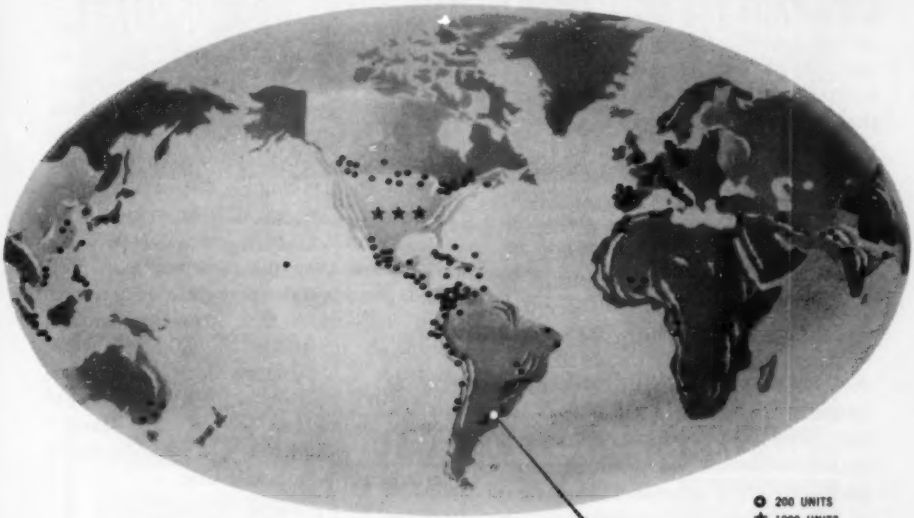
Salt water intrusion these days has become as much a mental as a hydrologic problem as a result of the current plethora of publicity and enthusiasm for desalinization. As we have, no doubt too often, remarked, we have no quarrel with desalinization as a means of providing an alternate source of fresh water supply and we favor research into economical methods now so that they will be available when needed, but it is the byproducts of the publicity and enthusiasm that cause us concern. One of these byproducts is the overconcentration of research effort on desalinization as against other means of water resource development and conservation; the other is the general misunderstanding of the public concerning the real cause of local water shortages.

By "overconcentration" of research effort on desalinization, we do not necessarily mean that too much desalinization research is now being done, but there is certainly an imbalance between the expenditure of research effort in this and other fields of water resources. In government-sponsored research, for instance, such programs as those of evaporation control, pollution control, and ground water recharge, which, in conserving water that is already fresh and available, can be of much more immediate benefit to many more communities, have been treated as poor relations in comparison with the desalinization program. And, where industry's research into desalting methods must be measured in billions of dollars, its research into better methods of utilizing water and of treating wastes is relatively very small. Industry's research effort will understandably be governed directly by the possibilities for profit. But certainly the program of the federal government could be undertaken on a more logical basis if all research into water resources development and conservation were under the same agency, permitting the appropriations for water research to be divided among the various programs in some relation to their prospects and to the priority of the problem involved.

The general misunderstanding of the public concerning the real cause of local water shortages is the inevitable result of the "crisis" approach employed to tell the story of water in practically all the communications media. For instance, happy as we were with most of the material in the CBS telecast on the water problem last Oct. 19, its title—"The Water Famine"—and one of the opening statements—"there is no one who contends that enough water is available for all who need it now!"—certainly served to create the impression that we are, as the New York *Times* phrased it, "approaching the brink of a critical water storage." And virtually every one of the wonderfully many newspaper and magazine articles on water that we have seen of late cites the facts that we are now using more than 300 bgd, that available supply now is 515 bgd,

(Continued on page 40 P&R)

SOLIDS-CONTACT UNITS AROUND THE WORLD



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Water treatment around the world is synonymous with INFILCO.

We were pioneers in the development of high-rate solids-contact units, and have supplied them to the world market for more than a quarter of a century.

More than five hundred "ACCELATOR" installations in foreign lands attest to the company's international leadership. More than three thousand domestic installations confirm it.

"ACCELATOR" solids-contact clarification units are installed in twenty-six capital cities of the free world.

The latest example is South America's largest high-rate water treating plant at Montevideo, Uruguay. INFILCO equipment was chosen because it will double production of the existing plant in half the space, and do it more efficiently.

These are typical advantages of INFILCO installations. Whether your problems are large or small, INFILCO can help you whatever your water treatment problem. It pays to plan with INFILCO, the largest supplier of high-rate water treating equipment in the world.

See your Consulting Engineer and write today for Bulletin 80-A, condensed catalog of INFILCO equipment.

Preliminary sketch of Montevideo, Uruguay plant showing four ACCELATOR® type SR units with total capacity of 116,000,000 GPD.

INFILCO GENERAL AMERICAN

INFILCO INC.

General Offices — Tucson, Arizona
Field offices throughout the U. S. and in other countries
Subsidiary of General American Transportation Corporation

556 A

(*Continued from page 38 P&R*)

and that we will require more than 515 bgd by 1980. The fact that, of the 300 bgd, only 60 bgd is "consumptive" use and that consumptive use will probably be less than 120 bgd in 1980 has not penetrated to either the press or the public. And until that basic understanding does penetrate, it will continue to be an uphill struggle for the water utility field to convince the public that the real cause of local water shortages is not lack of water but lack of facilities to store, treat, and deliver the water when and where it is needed.

All this concern, of course, ignores the merits of the desalinization program as an instrument of foreign policy, as a means of throwing some salt on Sputnik's tail, as a means of making the deserts bloom with food for the hungry of the world. On that basis, the seemingly disproportionate research effort could undoubtedly be justified, if not magnified, and the cry of crisis as well. But that is not how the program is now being justified—and, were it, we presume that the Office of Saline Water would be claimed by the Department of State from the Department of Interior and we would soon be concerned with salt water extrusion.

Meanwhile, the Post Office Department is already in the act, giving consideration to a 1962 stamp commemorating the desalinization program, thus creating, as *The Stamp World* expresses it, "a striking messenger of this great undertaking." "America's use of water," we learn from the *World*, "is increasing at a rapid rate. By 1980, we may need as much as 600 bgd, double our present daily usage. To help meet this growing demand upon the limited fresh-water resources, science is looking to an unlimited supply—the millions of cubic miles of ocean bordering 24 of our states." And we would hope that such a stamp would provide a salt lick.

Fluorinews seems to have picked up in the past few months, coming in from all directions:

(*Continued on page 42 P&R*)

This Month Years Ago

December 1911—Another typhoid fever outbreak at Trenton, N.J., apparently due to the sewage-diluted Delaware River water supply, was reported. From Nov. 1 to Dec. 9, there were reported to the State Board of Health 89 cases of the disease.

Filtered water for all Philadelphia became available with the opening of the 70,000,000-gal plant at Queen Lane. In round numbers, the water consumption of Philadelphia was 200 gal per capita.

The city of Appleton, Wis., purchased the water plant of the Appleton Water-Works Co. for $255,000. At that time the water was obtained from the Fox River and filtered through "some rather crude wooden tub filters."

"The (Kansas) State Board of Health now has a portable plant for the treating of municipal water supplies with calcium hypochlorite. It consists essentially of three substantial oak barrels, a specially-designed orifice box, and the necessary valves and connections.

The Bull Run Conduit, just completed to supplement the volume of water supply for Portland, Ore., consisted of 10 miles of 52-in. and 14 miles of 44-in. lock-bar pipe.

Mr. Mayor! Mr. City Commissioner! Mr. City Engineer!

Proved PERFORMANCE—Not Promises Backs CAST IRON PRESSURE PIPE

Your taxpayers have entrusted you with a decision—long-range in nature and far-reaching in consequences—to purchase pipe for your community's water system addition. Whether you borrow money or use current funds, you can't afford to take a chance on pipe that is unproven, with many failures in less than 20 years.

CAST IRON PRESSURE PIPE

Has Established Its Superiority With Many Records of Service Like These:

at MONTREAL since 1816 —	144 YEARS
at LYNCHBURG since 1828 —	132 YEARS
at PHILADELPHIA since 1830 —	130 YEARS
at RICHMOND since 1831 —	129 YEARS
at BALTIMORE since 1834 —	126 YEARS
at ST. LOUIS since 1834 —	126 YEARS
at READING since 1834 —	126 YEARS
at HUNTSVILLE since 1836 —	124 YEARS
at LANCASTER since 1836 —	124 YEARS

If you want more proof, we can supply it. Sixty-eight cities are still using Cast Iron Pipe more than 100 years old. Join the Century Club! Safeguard your city's welfare with the only pipe that has stood the test of time.

This advertisement is published in the interests of the Cast Iron Pressure Pipe Industry by.....

WOODWARD IRON COMPANY

Since 1882

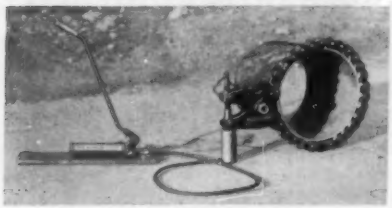
WOODWARD, ALABAMA

NOW AVAILABLE!

THE WHEELER

"SUPER"

HYDRAULIC PIPE CUTTER



for 10" thru 20"

CAST IRON WATER MAIN

No rotating—all you do is wrap the chain around the pipe, engage it in the cutter's upper jaws, adjust out slack and operate pump.

JUST

SQUEEZE AND POP!

For pipe sizes up to 12" we recommend our Heavy-Duty Hydraulic shown here in the act of cutting a section of large diameter pipe.

The Wheeler Mfg. Corp.

P. O. Box 688

Ashtabula, Ohio

(Continued from page 40 P&R)

• From New Jersey came word that State Health Commissioner Roscoe P. Kandle had sent a letter to the mayors of all 526 communities in the state where the fluoride level of the water supply is below the optimum "emphatically recommending" fluoridation. Followup stories indicated that the ignition was only spotty and that no real action had resulted by the end of October.

• From Kansas City, Mo., where the battle had made the heat of summer seem cool, came the report that the city council had, on Sep. 22, approved fluoridation and authorized negotiation of a contract to spend $65,000 for purchase of the necessary equipment.

• Salt Lake City, Utah, prepared to present the issue to its voters.*

• The Iowa Supreme Court unanimously upheld the right of Iowa cities to add fluorides in the exercise of their police powers.

• The Tennessee department of health announced that a 10-year study of tooth decay in children from Milan, which fluoridates, and Trenton, which does not, showed Trenton children to have four times as many cavities as those from Milan.

• The New York State Dental Health Bureau, reporting on a 17-year study of 100 children at Newburgh, indicated that fluoridated water, in addition to caries control, may contribute to the development of straight teeth.

Meanwhile:

• The American Dental Association reaffirmed its recognition of Crest toothpaste.

• Dominion Fluoridators Ltd. of Toronto began to explore the possibility

* Post-Nov. 7-Script: Fluoridation lost, not only in Salt Lake City but in Springville, Sunset, and American Fork also, and by wide margins.

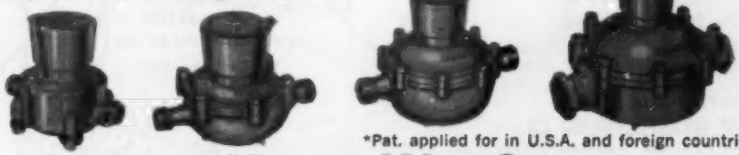
(Continued on page 44 P&R)

Bigger face, better features make new Badger *Easy-Read** a standout

Look at this actual-size Easy-Read face — its digits are ¼" high! This magnetic drive meter has more exclusives: *Sealed, removable register* (comes off without disturbing the meter itself)... *Truly permanent magnetic coupling* (it's rustproof and noncorrosive)... *Interchangeable parts.* And because Easy-Read's register and gear train parts operate in a clean, dry lubricated, sealed housing, fogged registers are completely eliminated.

Ask your Badger representative for full details and demonstration of the new Easy-Read magnetic drive meter.

Split-case Easy-Read meters ⅝" through 2"
Frostproof models ⅝" through 1" x 1¼"



*Pat. applied for in U.S.A. and foreign countries

Badger Meter Mfg. Company

4545 West Brown Deer Road • Milwaukee 23, Wisconsin

(Continued from page 42 P&R)

of marketing its sink-attached home fluoridation unit in the United States.

• A staff member of the National Institute of Dental Research at Bethesda, Md., reported that animal studies indicated that dental caries may be a "transmissible infectious disease" susceptible to control by an anti-decay vaccine.

• And Dr. F. B. Exner, M.D., F.A.C.R., of Seattle, Wash., wrote us a letter.

If the obvious bias used in selecting excerpts from my writings in the item entitled, "Fluoridation causes high blood pressure . . ." [September P&R, pp. 40 and 42] reflects editorial policy, it is obviously useless to offer any protest.

I would point out, however, that despite the biased selection the quotations from me were factual statements which are subject to proof or disproof; and that while you chose to ignore the supporting evidence, it has never been refuted.

On the other hand, the excerpts from Dr. Frederick Stare consisted of personal attacks and ridicule. The single exception is his claim that people are denied good teeth by the rejection of fluoridation. This is patently false. No one is denied the "benefits" (if any) of fluoride by its absence from the water. It is readily and cheaply available to any who want it; and if given individually, in measured doses, it cannot help but be safer and more dependable than if you put it in the water and trust to luck that every child will get the "right" amount.

Plain water, long famous as a senatorial bourbon diluent, is apparently unworthy of the upper chamber itself.

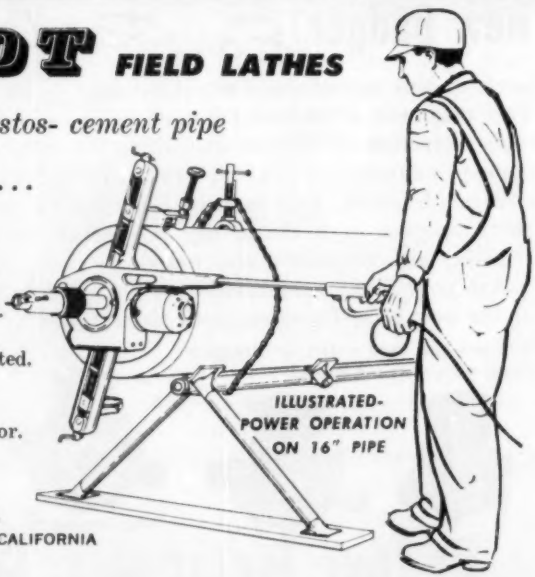
(Continued on page 46 P&R)

PILOT FIELD LATHES

machine asbestos- cement pipe

right on the job . . .

Make factory-like ends
on any length when
and where you need them.
No waiting — no delay.
Power or manually operated.
All sizes to 4" thru 20"
Write for details and
name of nearest distributor.



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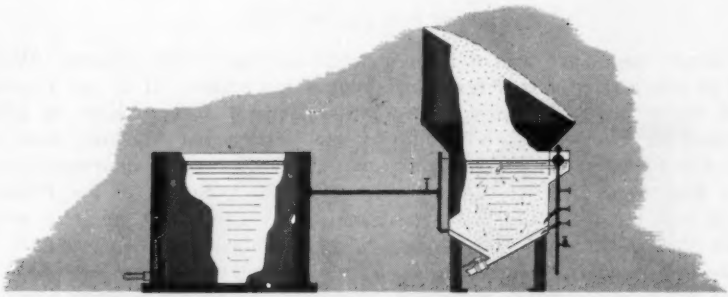
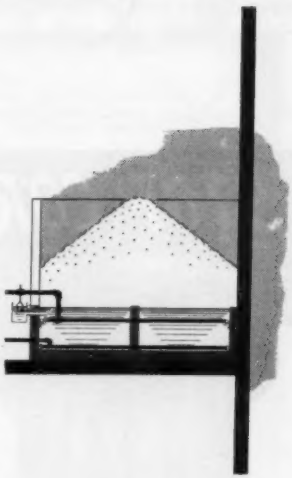


SALT STORAGE

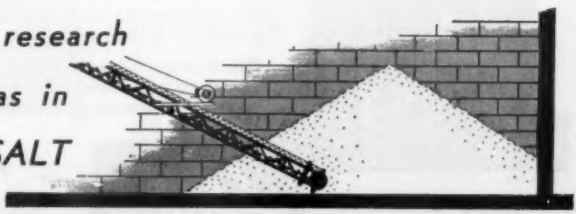
How it can affect design of water softening installations

The method used to store salt must be considered when planning a water softening plant. Dry salt storage, for example, requires different facilities from brine storage. And "wet storage" (dry salt stored under covering brine) has its own special design needs. Whatever method is chosen, however, its effect on plant design is greater than ever, since **more** salt and brine are needed in today's higher-capacity softening plants.

If you would like help in planning modern, large-scale salt-storage facilities, contact International Salt Company. With over 50 years of experience and continuing research in all phases of salt handling and brine production, International can suggest many new and practical ideas in connection with salt purchase, storage and dissolving for regenerating ion exchangers. This service is impartial and comprehensive. It costs you nothing.



Service and research are the extras in STERLING SALT



INTERNATIONAL SALT COMPANY, CLARKS SUMMIT, PA. • **Sales Offices:** Boston, Mass. • Buffalo, N. Y. Charlotte, N. C. • Chicago, Ill. • Cincinnati, O. • Detroit, Mich. • Newark, N. J. • New Orleans, La. New York, N. Y. • Philadelphia, Pa. • Pittsburgh, Pa. • St. Louis, Mo.

(Continued from page 44 P&R)

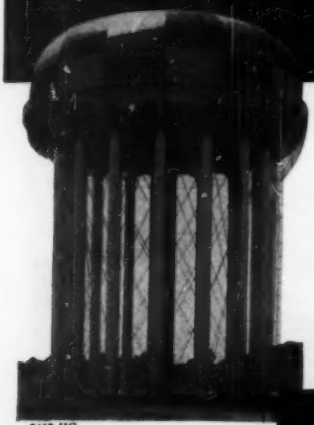
Thus, Senate pages are full of information on which senator requires what kind of water how. Latest communique from the Capitol on this significant subject appeared in the Des Moines *Register* a month or so ago. There it was recorded that Arkansas senators McClellan and Fulbright demand bottled Arkansas mineral water, that West Virginia senators Randolph and Byrd similarly insist upon mineral brew from their home state, and that most senators order their water cold, bottled, and often with a fizz, although most are not wedded to a specific geographic origin. Senators Joe Clark of Pennsylvania and Harrison Williams of New Jersey, being a little more democratic as well as Democratic, take theirs half and half—half mineral fizz water and half "plain ordinary" Washington tap water. It is not reported what Senator Robert Kerr of Oklahoma drinks, but knowing how exposed he has been to information concerning the pollution of the Potomac we would guess that he, too, would have specified mineral water if he hadn't also been exposed to AWWA last June in Detroit. Now he wouldn't, we are sure, dare—drink any but a safe public water supply, that is.

Come next election we're going to take it upon ourself to find out what the candidates drink! Our vote will be on tap!

Further anent Capitol water use, we note the hydrologic perspicacity of Secretary of Commerce Hodges in his

(Continued on page 48 P&R)

STOP CORROSION . . . IN WATER STORAGE TANKS



with Harco CATHODIC PROTECTION SYSTEMS

Everyday, electrolytic corrosion damages thousands of dollars worth of water storage tanks. Harco specialists can protect your investment with a cathodic system engineered to meet your needs.

Harco job-engineered installations include tests, drawings, materials, and installation as well as periodic maintenance services.

8419-HC

Write today for catalog or call VUlcan 3-8787.

Harco

THE HARCO CORPORATION

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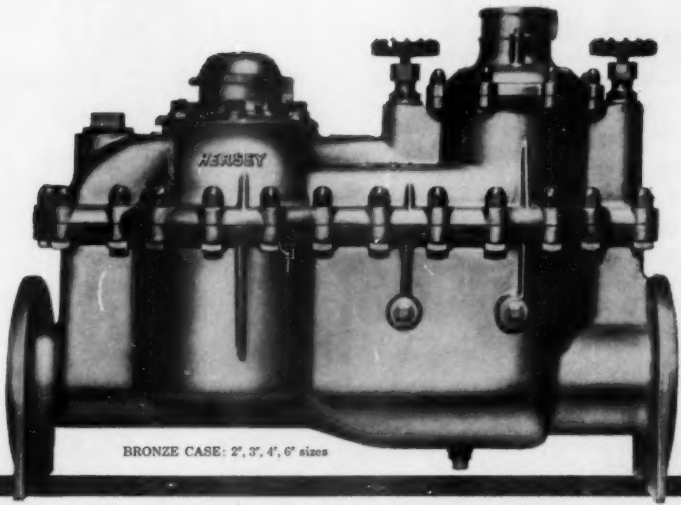


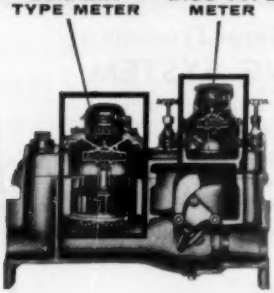
BRONZE CASE: 2", 3", 4", 6" sizes

The Proved Method of Accurately Measuring a Wide Range of Flows

HERSEY
COMPOUND METER
MODEL CT (BRONZE CASE)

For Large Rates of Flow
CURRENT TYPE METER

For Small Rates of Flow
DISC TYPE METER



Since 1932 this water meter has been the leader for measuring a wide range of flows. It combines a Current Type Meter (Model T) to measure high rates of flow with a Disc Type Meter (Model HD) to measure low rates of flow. A Hersey Automatic Lever Valve links these meters together, providing an integral device in one casing that accurately measures a larger range of flows than can be accomplished by either type of meter separately. The Automatic Valve is of the compound lever mechanical type which, when opened by a large demand, offers minimum resistance to the flow of water.

The Hersey Compound Meter, Model CT, combines accurate measurement at all rates of flow with a long-time, proved record of minimum maintenance requirements. An exclusive feature is the valves which make it possible to shut off the by-pass meter without closing down the main line meter. Write for more information.

Hersey-Sparling
Meter Company
HERSEY PRODUCTS
DEDHAM, MASSACHUSETTS

Branches: Atlanta, Boston, Chicago, Cleveland, Dallas, Denver, Kansas City, Mo., Los Angeles, New York, Philadelphia, Portland, Ore., Salt Lake City, San Francisco, Seattle.

(Continued from page 46 P&R)

advice concerning the use of paper towels:

If everyone washing his or her hands and using paper towels for drying would shake his hands and say "splat, spat" before using a group of towels, I'll bet the cost of towels could be cut in half.

Of course, if he'd go the whole goat and have his staff say:

Willing Water go away,
Evaporate!
Come again another day
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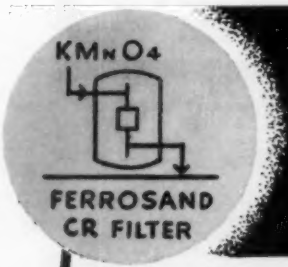
Mark D. Hollis, assistant surgeon general and chief engineer of USPHS for the past 12 years and an internationally known expert in his field, has been appointed chief engineer of the World Health Organization, with headquarters in Geneva. In his new position, he will direct the environmental health activities of WHO as carried out in 109 member countries.

He has retired from USPHS after a career of more than 30 years as an

(Continued on page 52 P&R)



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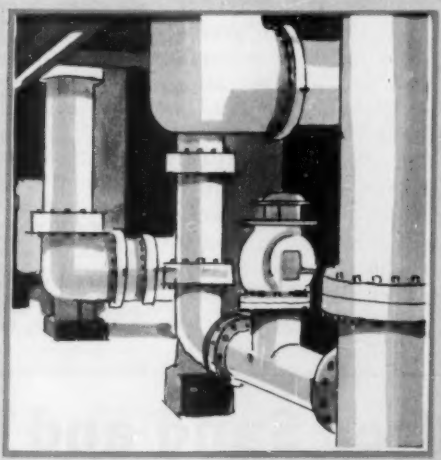

AMERICAN CAST IRON PIPE COMPANY
BIRMINGHAM ALABAMA

(Continued from page 48 P&R)

officer of the service, 25 years of them on active duty. A past-president of WPCF, he is a fellow of APHA and ASCE, and a diplomate of the American Academy of Sanitary Engineers.

J. Edward Metzger, Jr., director of the Richmond (Va.) Dept. of Public Utilities, died on Oct. 25, 1961, while working at his desk. He was 53 years old. After working for the Chesapeake & Ohio Railway Co., he joined the department in 1938 and was appointed to the position of director in 1948. His period of service was interrupted only by duty for a few months in 1953 as acting city manager. He was a member of AWWA since 1951.

Joseph D. O'Day, administrative director, Monroe County Water Authority, Rochester, N.Y., died on Oct 3, 1961, at the age of 57. A graduate of Pratt Institute in Brooklyn, N.Y., he joined the New York Water Service Corp. in 1927. In 1947–49 he served as chief engineer in the company's Syracuse division and held the same position in the Rochester division in 1950–54, when he became general manager of that division. In 1959, following acquisition of the company's Rochester properties by the Monroe County Water Authority, he became the authority's administrative director. He was a member of AWWA since 1955.

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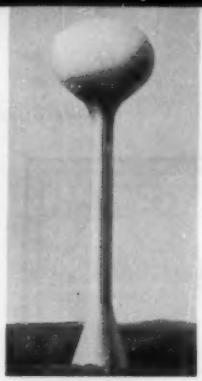

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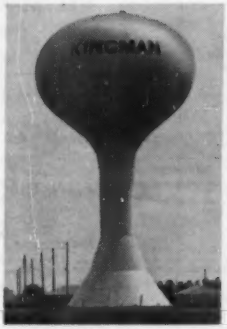

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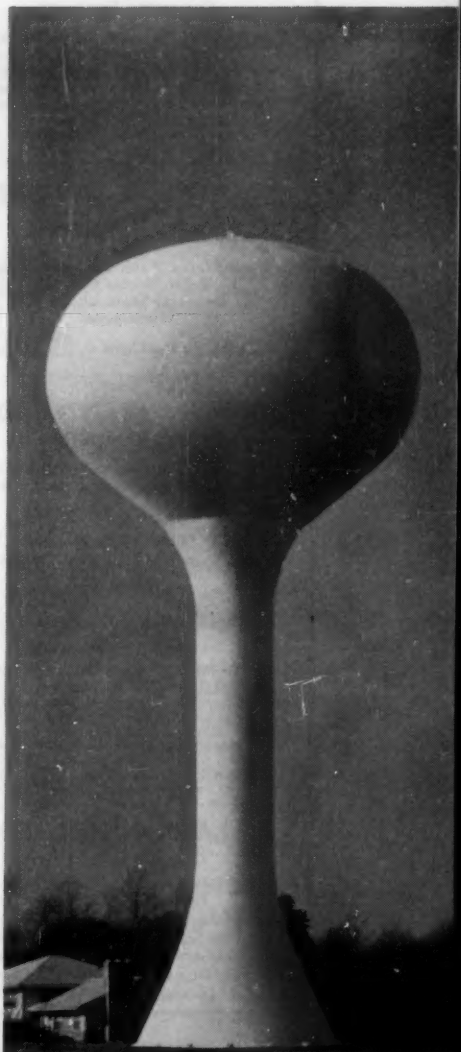

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Index of Abstracts

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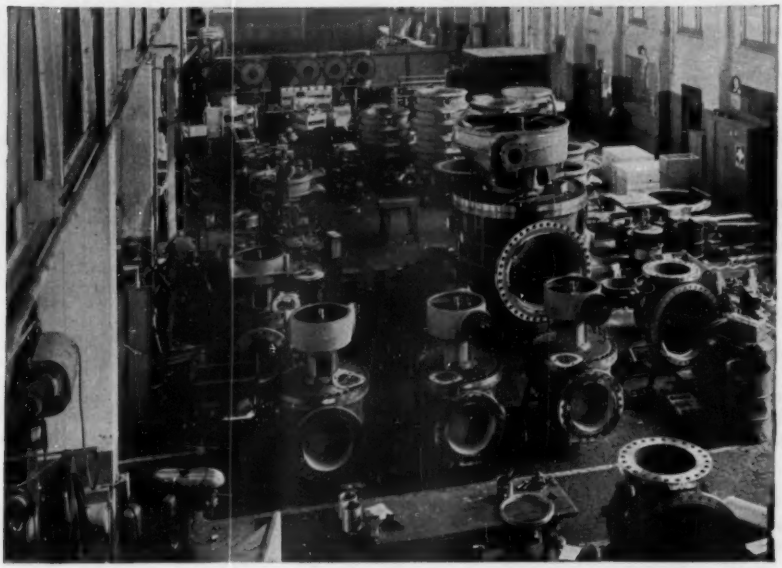

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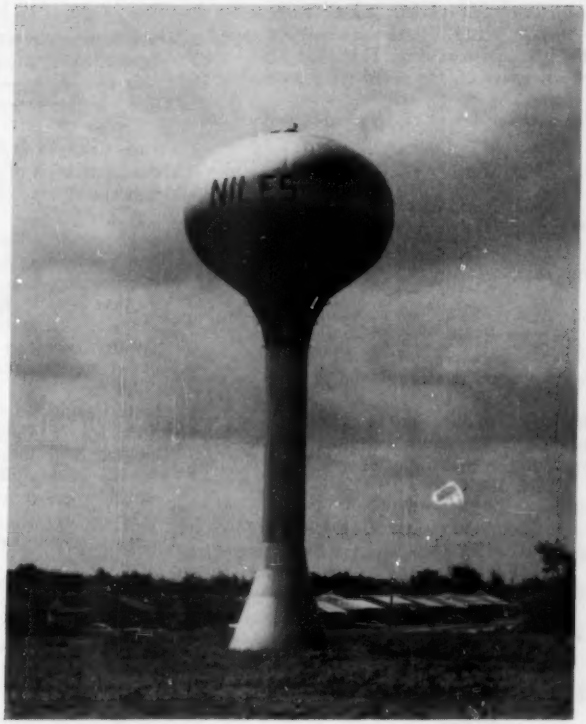

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Roll-call for water

When Wall Street, N.Y. Was Only a Stone Wall

After the Dutch bought Manhattan Island from the Iroquois Indians, they built a stone wall across the island to prevent possible attack by the English. That military barrier, built 308 years ago, is known today as Wall Street and is the financial center of the United States. Around it stands one of the largest cities in the world!

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Pennsylvania

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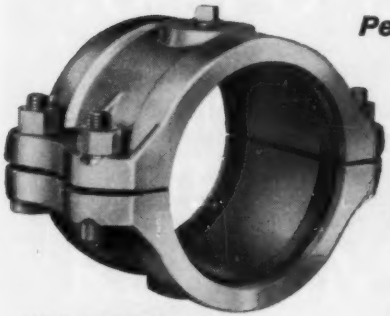
NEW CLOW
Ductile Iron Split Sleeve



Permits easier, quicker, permanent repair of 4", 6" & 8" transverse cast iron pipe underground breaks

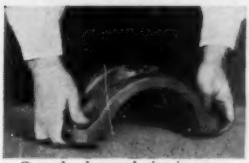
LIGHT WEIGHT Assembled 4" diameter sleeve weighs but 26 lbs. Weight of 6" sleeve is 32 lbs., 38 lbs. for 8" sleeve.

SHORT LENGTH Effective length of 4 inches between end seals on all sizes. Overall length is 6¼".

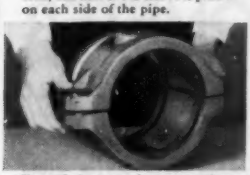
TWO-PIECE ASSEMBLY No end glands. Side and end gaskets are pre-assembled and cemented in sleeve grooves.

HIGH STRENGTH All parts are high tensile and corrosion-resistant. Sleeve halves are 70,000 psi tensile ductile iron. Nuts and bolts are high strength, corrosion-resistant alloy.

ASSEMBLED IN 3 EASY STEPS

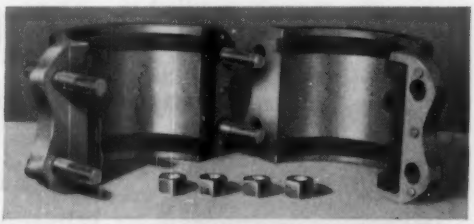


Once the damaged pipe is uncovered, one half of the sleeve is placed on each side of the pipe.



Sleeve halves are drawn together. Pre-assembled rubber gaskets make tight seal.

After the bolts are taken up finger-tight, tightening the four bolts by wrench completes assembly.



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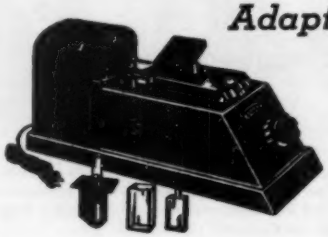

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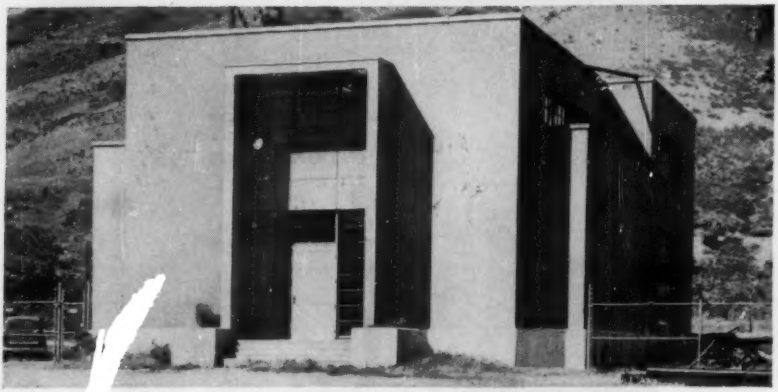
At Golden, Colorado

Hagan Coagulant Aid raises plant throughput by 43%



Water plant at Golden. Main water source is Clear Creek, a fast-flowing mountain stream.

Quick Case History—reading time 57 seconds

THE PLANT: Golden is a growing community, with a rapidly expanding industrial district. The water plant serves some 8,500 people, and must deal with the very turbid water of Clear Creek, which falls an average of 115 feet per mile. The water is first piped to a settling pond, then to a clarifier. Next, filtration, and then to the clear well.

THE PROBLEM: The water carries mine drainage, mud, silt, color and algae, so that, with the best of coagulation possible with lime and alum, turbidities of 20 ppm on top of the filters were not uncommon. Filter runs were short, and plant efficiency hard to maintain.

THE SOLUTION: The use of a coagulant aid was indicated, so an investigation of all available materials was made. Jar tests were used and after four months, the product that seemed to be best was Hagan Coagulant Aid No. 2. Next step was a plant trial, which confirmed laboratory findings.

RESULTS: Turbidity on the filters was reduced to 3 ppm, with zero turbidity after filtration. Plant throughput was increased from 1,500,000 to 2,200,000 gallons per day and backwashing was reduced. Over-all plant operating efficiency has increased by 97 percent. Since Hagan Coagulant Aids are effective over a wide pH range, treatment adjustments are rarely necessary.

THE PRODUCT: Hagan Coagulant Aids are non-toxic, easy to handle, and produce large, tough floc that speed settling time. The Aids are easy to feed, either dry or in slurry form, and are completely safe for use with drinking water. For more information on Hagan Coagulant Aids, write or phone the address below. **Ask for Bulletin HSP-919.**

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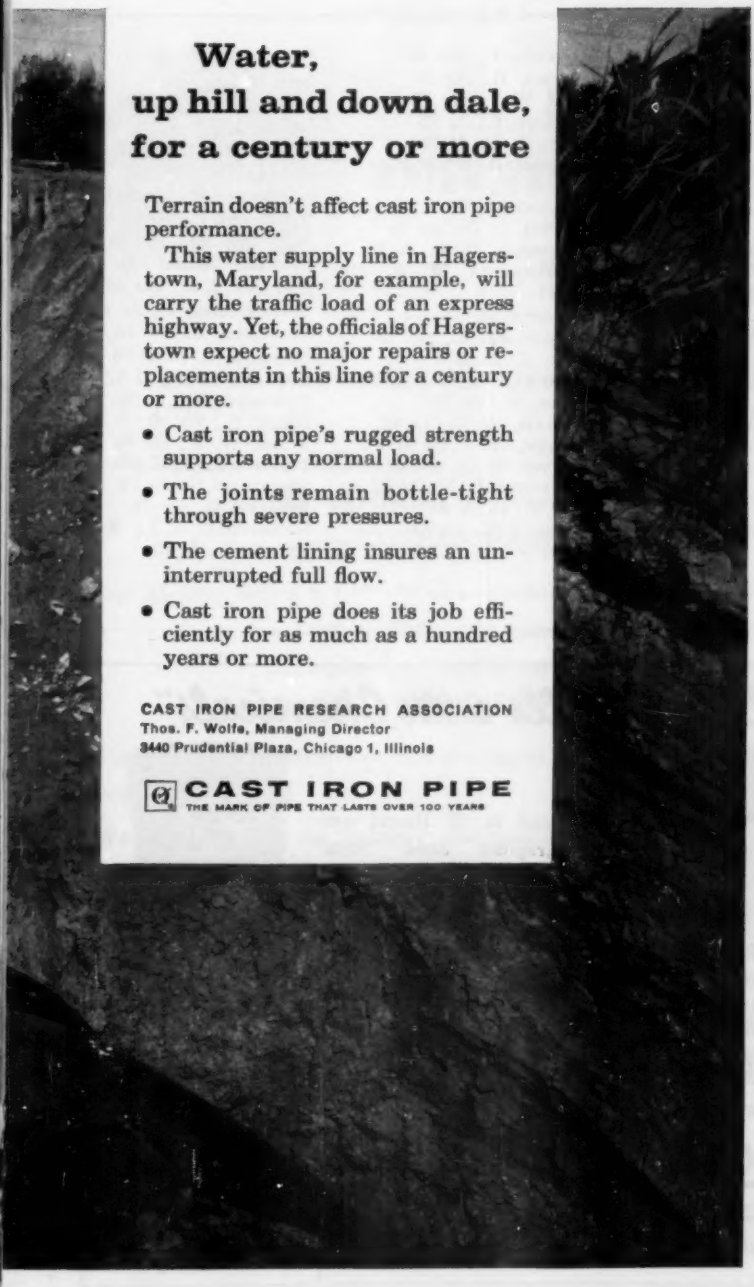

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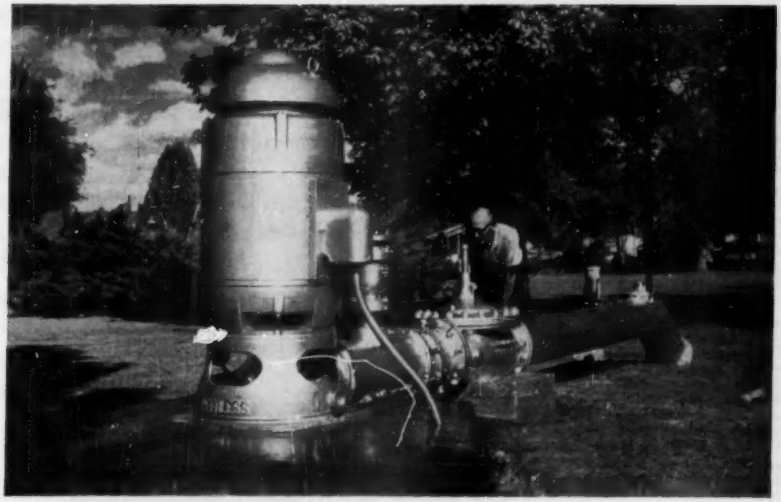

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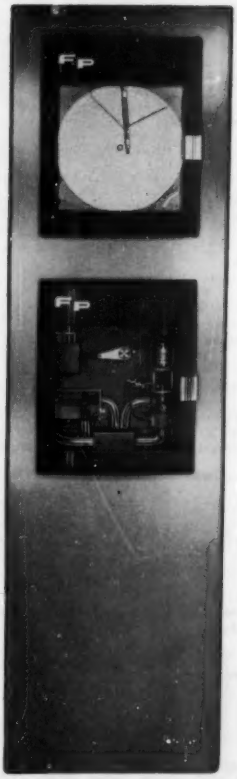
■ Here is the **Anachlor*** – the residual chlorine analyzer that's also an efficiency expert on water or sewage treating operations. It continuously measures Cl_2 residuals, frees personnel from routine checks, and saves on the cost of treatment chemicals. The Anachlor has two basic components, the analyzer unit where current proportional to the chlorine is generated, and the recorder or indicator with optional electric or pneumatic control elements. It can trim chlorinator feed rate and also transmit measured values to a remote station. It employs an electrode rotating at high speed so that a high velocity of sample flow is not necessary. The electrode cell is easily disassembled for cleaning by disconnecting one slip-on connection and two pins. You'll find the Anachlor equally suitable for water or sewage treating operations – easy to operate – easy to maintain – and thoroughly dependable.



The Anachlor is described in complete detail, from operating principles to control options, in Catalog 17B2200. This instrument is only one of many F&P components for automating water and waste treatment. For basic information or specific suggestions write Fischer & Porter Company, 1021 Fischer Road, Warminster, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2808 Jane Street, Toronto.

FP
FISCHER & PORTER COMPANY
CHLORINATION AND INSTRUMENTATION

*Anachlor is a trade name of Fischer & Porter Company

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Philadelphia Quartz Co.

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Copper Sulfate:
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Harco Corp.
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B-I-F Industries, Inc.—Omega
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Permutit Co.
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Mueller Co.

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Simplex Valve & Meter Co.
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Trinity Valley Iron & Steel Co.
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Infilco Inc.
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Ford Meter Box Co.
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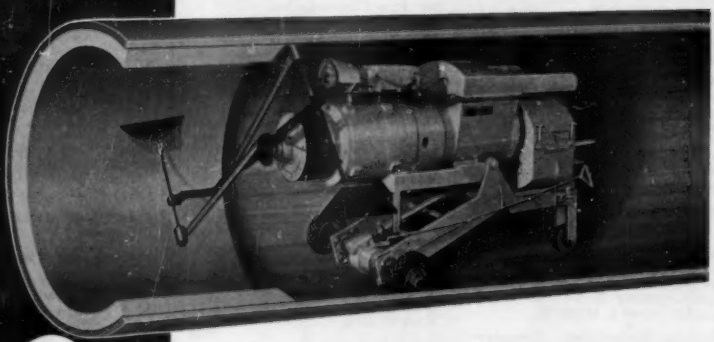

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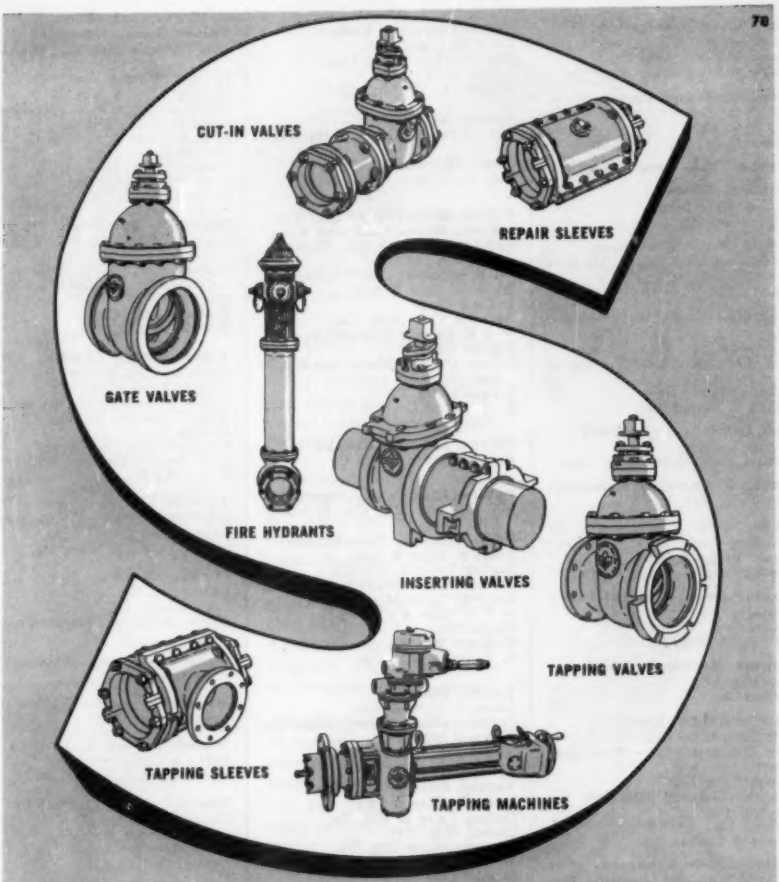

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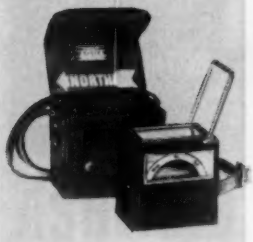
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1961 AWWA Directory.



"Only The Best"

For ordering dependable and proven pipe line equipment, consult your latest Pollard Catalog #27.

Included in the #27 Catalog, and displayed on this page, are the M-Scope Transistorized Combination Leak Detector and Pipe Locator, Audio-Scope, Geophone Leak Detectors, T-10 Electronic Box Locator, Aqua Valve Box Locator and Magnetic Dipping Needles for locating service boxes.

Hundreds of water departments all over the country are using Pollard "one order" service. You, too, can enjoy the advantages of ordering from the nation's #1 source for dependable pipe line equipment.

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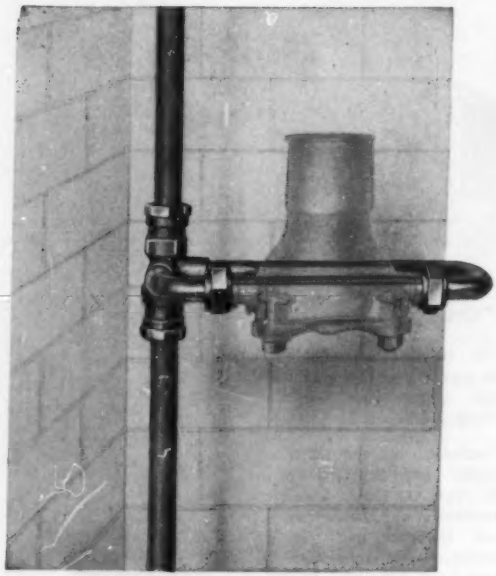


For Setting Meters in Basements

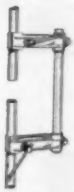
EASY TO INSTALL

The KORNERHORN

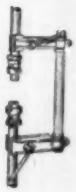
In a vertical basement pipe, against the wall or in a corner, the Kornerhorn makes a most satisfactory meter setting. Installation is fast and economical as pipe threading is eliminated. Send for detailed information.

When Valves are Needed

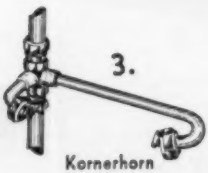
Ford Kornerhorn valves installed on the supply side, or on both sides of the Kornerhorn add extra convenience and cleanliness when meters are changed.



1. Cut supply line. Clamp not necessary but convenient



2. Add Connections



3. Kornerhorn in place

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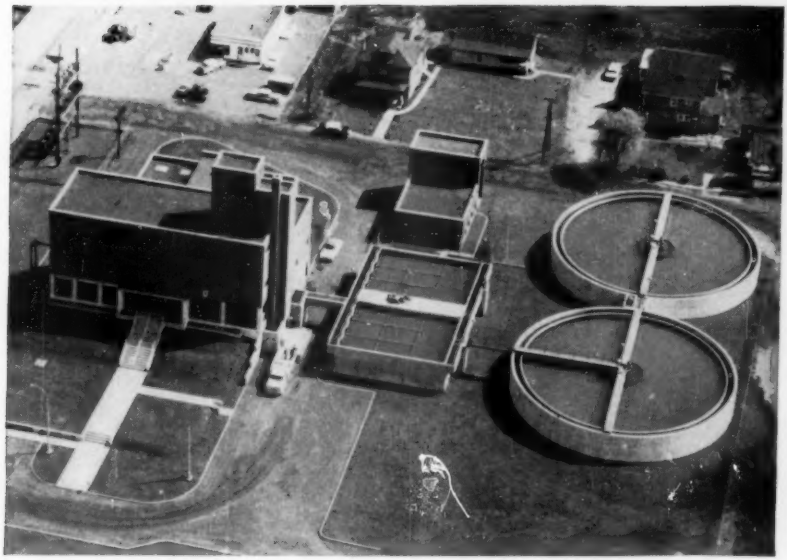
Wabash, Indiana

FORD



ASHLAND, Ky.'s NEW PLANT

Treats Ohio River Water in Dorr-Oliver Equipment

A quarter-century ago, the City of Ashland, Kentucky, installed a new water treatment plant which incorporated Dorrco® Flocculators. Today, removed from the earlier plant's flood-ridden area, an entirely new plant has been constructed, again incorporating Dorr-Oliver treatment units.

Located above the highest flood level, the new plant provides flocculation and clarification for 8 mgd of Ohio River water, with provision for expansion. These steps are carried out in one Dorrco TEQ Flash Mixer; two Dorrco Type T Flocculators with three rows of paddles 12′6″ dia.; and two Dorr Type S-7 Clarifiers 90′ dia. x 14′ s.w.d. – one equipped with T-type walkway.

Dorr-Oliver offers a wide range of equipment for the treatment of municipal water supplies. For complete information write Dorr-Oliver Incorporated, Stamford, Conn.

Consulting Engineers: Alfred LeFeber & Associates, Cincinnati, Ohio
Contractor: Wellsbach Corporation, Philadelphia, Penna.

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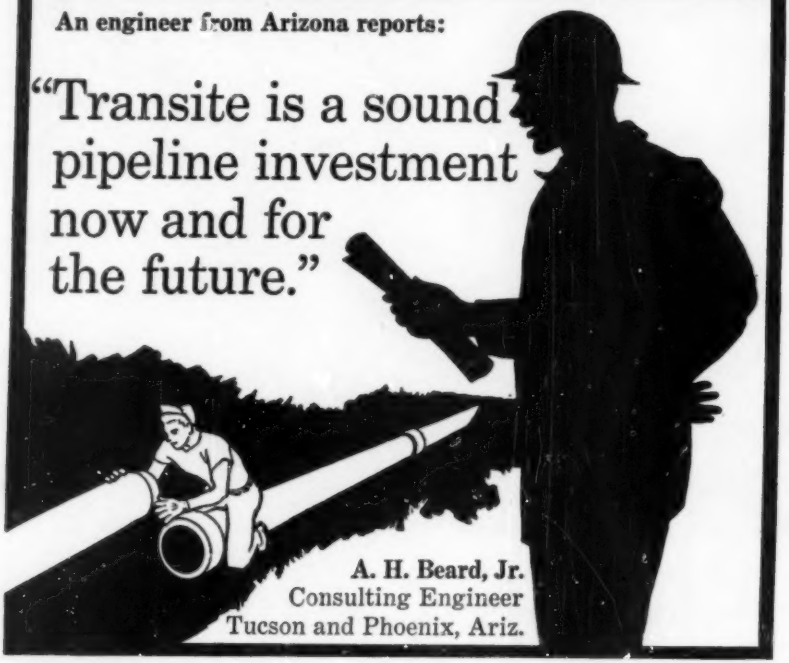

A. H. Beard, Jr.
Consulting Engineer
Tucson and Phoenix, Ariz.

"When considering a pipe material for water and sewage projects, 'value' analysis plays an important part in our choice. One of the main questions is whether the pipe will perform reliably now *and* in the future with cost advantages to the client.

"Experience has shown that Johns-Manville Transite® Pipe offers the value we seek. It has proved reliable and at very favorable costs. In addition to savings in handling and installing, Transite's unique Ring-Tite® joints assure that leakage tests will not upset job costs. In numerous tests, Transite lines have regularly been under the 'allowable' specification.

"Installations as old as Transite itself show this pipe outstanding under flexure, crush and hydrostatic conditions. Lengths of Transite excavated here in Arizona for tests showed no signs of internal corrosion after 20 years of dependable service."

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